Oxford Review Series

PHYSIOGRAPHY

NEW YORK
OXFORD BOOK COMPANY
Educational Publishers

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BY

ARTHUR H. KILLEN

Flushing High School, Flushing, L. I., N. Y.

NEW YORK

OXFORD BOOK COMPANY

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PREFACE

THE aim of this book is to present a comprehensive, accurate, and pedagogically sound review of physiography as taught in the best American high schools.

The following features recommend this book to teachers and pupils:

I. It is **up-to-date.** The content meets the very latest requirements for the subject as prescribed by the Board of Regents for the State of New York and by the syllabi of the best high schools in the country.

II. The **outline form** has been used, as far as possible, to help the pupil obtain a proper perspective of the subject.

III. Wherever possible, the material has been presented in **chart form**—the clearest and the most impressive form for review purposes.

IV. The **illustrations** are clear and well-labeled.

V. The **questions** at the end of each chapter have been very carefully selected from recent examination papers.

VI. Complete recent examination papers, set by the Board of Regents for New York State high schools as a final test of proficiency, have been placed at the end of the book. These papers provide additional drill material and familiarize the pupil with the type of question he will be expected to answer in the final examination.

The author wishes to express his appreciation to Mr. Howell R. Wood and Mr. Clarence H. Boden, both of the Science Department of Flushing High School, for their valuable suggestions and constructive criticisms.

FLUSHING, L. I., N. Y.
March, 1929.

A. H. K.

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PHYSIOGRAPHY

CHAPTER I

INTRODUCTION

I. Science.—Science is classified knowledge.

II. Physiography.—Physiography is the science which treats of—

A. The natural features of the surface of the Earth.

B. The changes which the surface of the Earth undergoes.

C. The relation between the surface features of the Earth and life.

III. Divisions of Physiography

A. *Mathematical Geography* treats of—

1. The shape, size, and motions of the Earth.
2. The determination of positions and distances on the surface of the Earth.
3. The representation of the Earth by means of globes and maps.

B. *Physical Geography* treats of—

1. The natural divisions of the surface of the Earth.
2. The distribution of plants and animals on the Earth.
3. Climate.

C. *Meteorology*—the scientific study of weather and climate.

D. *Structural Geology*—the study of rock formation, and of the physical and chemical changes which rocks have undergone in the past and are undergoing now.

E. *The study of the Earth as a planet* in its relation to the rest of the universe.

IV. Reasons for Studying Physiography.—The study of physiography—

A. Stimulates our imagination.

B. Increases our powers of observation.

C. Trains us in the scientific method of thinking.

D. Gives us a wealth of information and helps us understand our environment.

E. Helps us understand why it is important to conserve our natural resources, such as forests, coal, and water power.

QUESTIONS

1. Define: *science; physiography.*

2. What are the divisions of physiography?

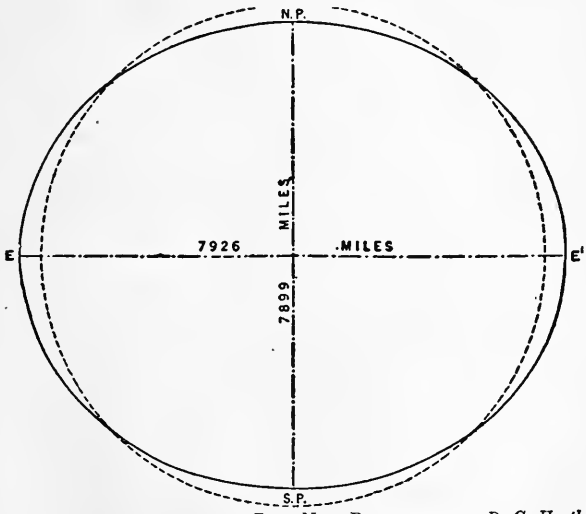
3. Of what does each of the following treat: (a) mathematical geography; (b) meteorology?

4. State four reasons for studying physiography.

CHAPTER II

THE EARTH AS A PLANET

I. Form of the Earth.—In form, the Earth differs very little from a perfect sphere. In the past, surface tension and the force of cohesion tended to give it the shape of a sphere, but the rotation of the Earth on its axis caused it to flatten a little at the poles and to bulge a little at the equator. The resulting form is that of an *oblate spheroid.*



From New Physiography, *D. C. Heath & Co.*

Fig. 1.—Size and Shape of the Earth

II. Proofs that the Earth is Spherical in Shape

A. When a ship recedes to the horizon, it gradually disappears from hull to mast; when it approaches

from the horizon, it reappears from top of mast to hull.

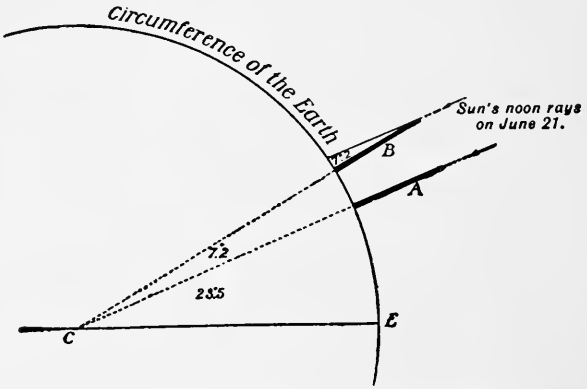
B. The Earth casts a circular shadow on the Moon during an eclipse.

C. When one ascends to a height, the horizon appears to sink and widen out.

D. The appearance of the heavens changes as one travels north or south; *i.e.*, some stars sink below the horizon, while others rise into view.

E. The Earth has been circumnavigated.

III. Size of the Earth.—At the equator, the diameter of the Earth is 7926.60 miles, but along the axis of rotation it measures only 7899.76 miles. The difference between the two diameters is therefore 26.84 miles. The distance around the Earth at the equator *(circumference)* is approximately 25,000 miles.



From New Physiography, *D. C. Heath & Co.*

Fig. 2.—The Method of Eratosthenes

IV. The Problem of Eratosthenes.—Eratosthenes (3rd century B.C.) was the first to measure the diameter of the Earth. He found that a certain pillar at Syene in Egypt, 500 miles south of Alexandria, cast no shadow at the time of the summer solstice. He found also that, at the same time, a vertical pillar at Alexandria cast a shadow which made

an angle of 7.2° with the pillar. Using this information, he solved the problem as follows:

A. Vertical pillars would, if extended far enough, meet at the center of the Earth (Fig. 2).

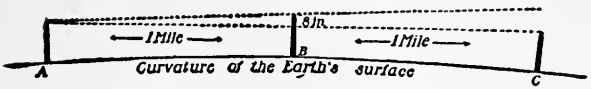
B. Since the rays of the Sun are parallel, the angle at C is equal to the angle at B (alternate interior angles of parallel lines).

C. Since the angle at the center is 7.2°, the arc which it subtends is also 7.2°.

500 miles $\div$ 7.2° = 69.4 miles per degree.

69.4 miles $\times$ 360° = 24,984 miles = circumference of Earth.

24,984 $\div$ 3.14 (π) = 8,000 miles (*approximately*) = diameter of Earth.



From NEW PHYSIOGRAPHY, *D. C. Heath & Co.*

FIG. 3.—THE WATER LEVEL METHOD

V. The Water Level Method.—If three posts A, B, and C (Fig. 3), are set up along the shore of a lake at intervals of one mile, and an observer sights from the top of A to the top of C with a telescope, the middle post B will be found to project 8 inches above the line of sight between the tops of the other two posts.

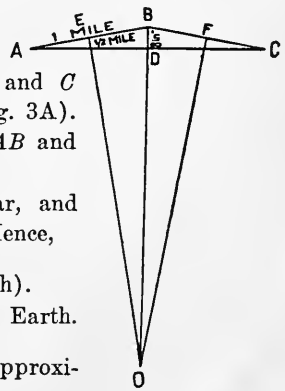


FIG. 3A

Calculation.—The three points A, B, and C (Fig. 3), determine the triangle ABC (Fig. 3A). The perpendicular bisectors of the sides AB and BC meet at O, the center of the Earth.

Triangles ABD and BOE are similar, and therefore their sides are in proportion. Hence,

$BD : AB = EB : BO$ (radius of Earth).

8 in. : 1 mile = 1 mile : diameter of Earth.

Solving, we obtain 7920 miles as the approximate diameter of the Earth.

VI. Density and Weight of the Earth.—The Earth weighs about 5½ times as much as a sphere of water of the same volume. Since the rocks on the surface of the Earth are only about 2½ times as dense as water, we conclude that the interior of the Earth is very much denser than the rocks at the surface. Other evidence tends to prove that the interior of the Earth is composed largely of iron.

> **Note.**—The weight of the Earth has been estimated to be 6×10^{21} tons.

VII. Motions of the Earth.—The Earth has two principal motions—*rotation* on its axis and *revolution* around the Sun. The Earth rotates once in 24 hours, or 15° in 1 hour. It travels around the Sun in 365.24 days.

> **Note.**—The Earth rotates on its axis from west to east.

VIII. Effects of the Earth's Rotation.—The rotation of the Earth on its axis

A. Produces daylight and darkness from east to west.

B. Causes the Sun, Moon and stars to *appear* to rise in the east and set in the west.

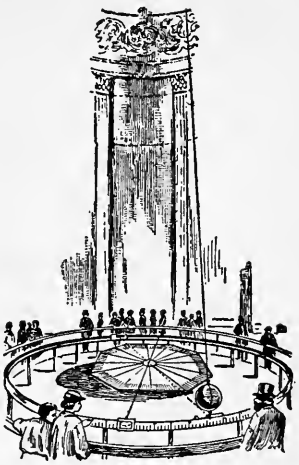
C. Determines the length of day.

D. Caused the flattening of the Earth at the poles and the bulging at the equator.

E. Causes winds and ocean currents to be deflected to the right in the northern hemisphere, and to the left in the southern hemisphere.

F. Causes a slight decrease in weight as one travels from either pole to the equator.

IX. Foucault's Pendulum Experiment.—This experiment to prove that the Earth rotates was first performed by Foucault, a French physicist. He suspended from the dome of the Pantheon in Paris a heavy iron ball attached to a steel wire about 200 ft. long. As the pendulum vibrated, its plane of vibration seemed to rotate slowly to the right. In reality, the pendulum maintained parallelism; it was the Earth under it that changed its position, because the Earth itself was rotating.



From NEW PHYSIOGRAPHY, *D. C. Heath & Co.*

FIG. 4.—FOUCAULT'S EXPERIMENT

X. Effects of the Earth's Revolution.—The revolution of the Earth around the Sun—

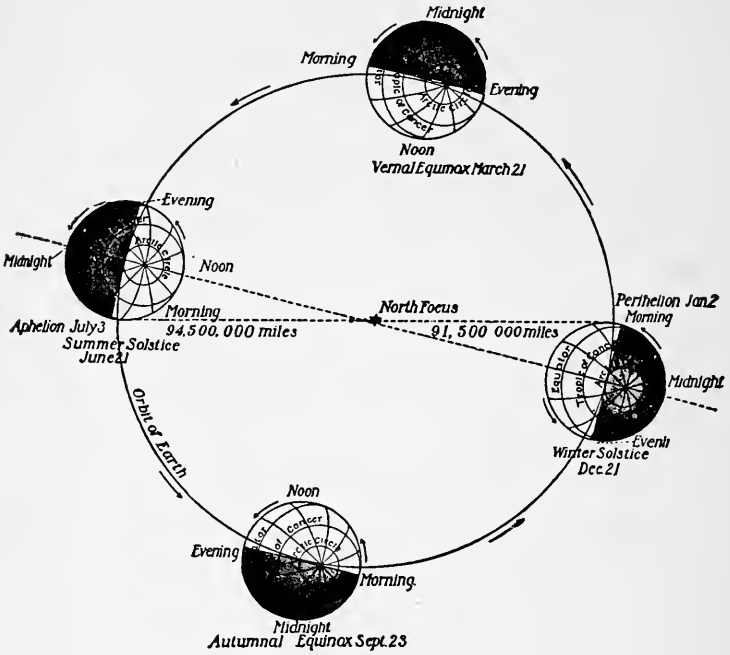
A. Causes the stars to *appear* to shift to the west about one degree each day. This, in turn, causes the stars to rise about four minutes earlier each night. Different constellations are therefore visible at different seasons of the year.

B. Causes the changes of seasons. These changes are due not merely to the revolution of the Earth around the Sun, but also to the facts that—

1. The Earth's axis is inclined 23½° to a perpendicular to the Earth's orbit.
2. The Earth's axis maintains parallelism.

XI. The Earth's Orbit.—The orbit of the Earth is an ellipse having the Sun at the north focus. The following

important positions of the Earth in its orbit are indicated in Fig. 5.



From NEW PHYSIOGRAPHY, *D. C. Heath & Co.*

FIG. 5.—IMPORTANT POSITIONS OF THE EARTH IN ITS ORBIT

A. *Perihelion.*—When the Earth is nearest to the Sun it is said to be at *perihelion.* This occurs on January 2, when the Earth is 91½ million miles from the Sun.

B. *Aphelion.*—When the Earth is farthest from the Sun it is said to be at *aphelion.* This occurs on July 3, when the Earth is 94½ million miles from the Sun.

C. *The Summer Solstice.*—This occurs on July 21, when the north pole of the Earth points toward the Sun. The line dividing daylight from darkness is tangent to the Arctic and Antarctic circles, the North Frigid Zone being in full daylight. The Sun is then vertically over the Tropic of Cancer.

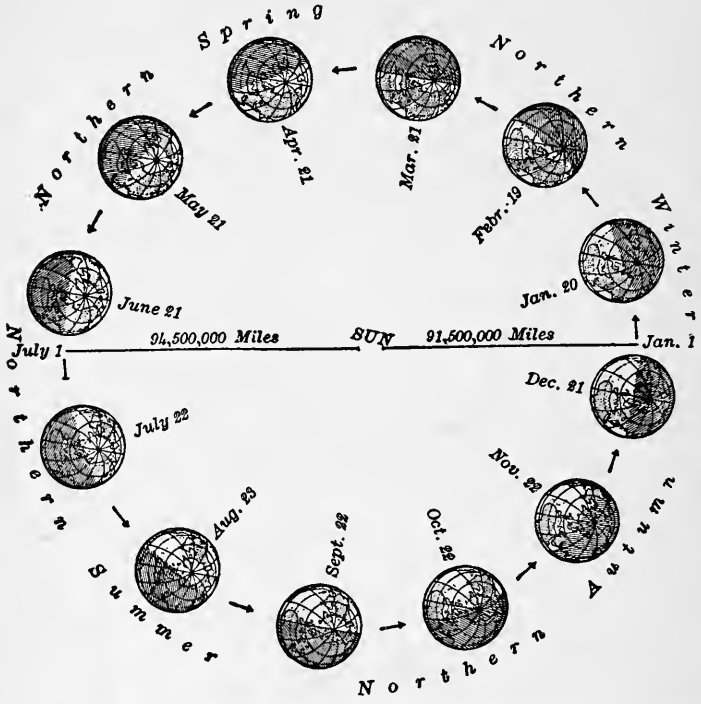
D. *The Autumnal Equinox.*—This occurs on September 23, when the line dividing daylight from darkness passes through both poles. The Sun is then vertically over the equator, and day and night are of equal length everywhere on the Earth.

E. *The Winter Solstice.*—This occurs on December 21, when the north pole of the Earth points away from the Sun. The line dividing daylight from darkness is tangent to the Arctic and Antarctic circles, the North Frigid zone being in total darkness. The Sun is then vertically over the Tropic of Capricorn.

F. *The Vernal Equinox.*—This occurs on March 21, when the line dividing daylight from darkness passes through both poles of the Earth, just as on September 23. The Sun is then vertically over the equator, and day and night are of equal length everywhere on the Earth.

XII. Unequal Days and Nights.—The axis of the Earth invariably points toward the Pole Star and hence maintains parallelism; *i.e.,* its position at any given time is parallel to every other position which it occupies. The result of this is that for six months the north pole gradually turns toward the Sun as the Earth moves forward in its orbit (Fig. 6). The days, therefore, gradually become longer in the northern hemisphere and shorter in the southern hemisphere. The reverse of this takes place during the next six

months. At the equator, days and nights are always of equal length; elsewhere, only on the dates of the equinoxes.



From Davis's Elementary Physical Geography, *Ginn & Co.*

Fig. 6.—Change of Seasons

As the Earth revolves, the gradual turning of its axis toward, and then away, from the Sun causes the change of seasons.

XIII. Change of Seasons.—As the days become longer and the Sun's rays become less slanting, the amount of heat received by the northern hemisphere gradually increases. This takes place from December 21 to June 21, when winter gradually gives way to spring and spring to summer. From June 21 to December 21 the days gradually grow shorter,

the Sun's rays become more slanting, and summer changes to fall and fall to winter.

QUESTIONS

1. What are the four strongest evidences that the Earth is spherical in shape?

2. Explain how Eratosthenes calculated the length of the Earth's diameter.

3. In digging a canal, would engineers have to allow for the curvature of the Earth? Explain.

4. (a) What causes the succession of day and night? (b) Why does the Sun appear to move across the sky from east to west?

5. (a) How long does it take the Earth to go completely around the Sun? (b) What name do we give to the path that the Earth follows?

6. Discuss the effects of (a) the rotation of the Earth on its axis; (b) the revolution of the Earth around the Sun.

7. What would be the length of our day and night if the period of the Earth's rotation were equal to its period of revolution?

8. (a) What causes the changes of seasons? (b) How would it affect the changes of seasons if there were no inclination of the Earth's axis? If there were a less inclination? If there were a greater inclination?

9. What would be the effect on the changes of seasons if the period of the Earth's revolution were (a) longer; (b) shorter?

10. What is meant by (a) solstices; (b) equinoxes? On what dates do they occur?

11. (a) On what dates does the Sun rise exactly in the east? (b) Between what dates does it rise north of east? South of east?

12. How far north must one travel to see the midnight Sun?

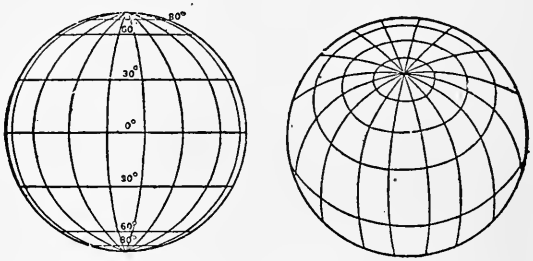
CHAPTER III

LATITUDE, LONGITUDE, AND TIME

I. Reference Lines.—In order to determine the exact location of a town or farm on land, or of a ship on the ocean, it is necessary to have a system of reference lines. In a well-laid out city it is easy to locate a given house by reference to numbered streets and avenues. Likewise, on a map or chart we can locate a given point by reference to numbered *meridians and parallels of latitude.*

II. How Reference Lines Are Determined.—On a smooth sphere it is difficult to fix a point from which measurements may be made. In the case of the Earth, however, its rotation determines the axis of rotation and therefore the poles and equator, and thus gives us a starting point for building up a system of reference lines.

III. Kinds of Reference Lines



From Physiography for High Schools, *Henry Holt & Co.*

Fig. 7.—Parallels and Meridians on a Globe

A. *The Axis of Rotation.*—The axis of rotation is an imaginary line on which the Earth rotates. Its ends are the north and south poles.

B. *The Equator.*—The equator is a great circle midway between the two poles and at right angles to the axis of rotation. As its name implies, it divides the Earth into two equal parts.

C. *Meridian Circles.*—Meridian circles are great circles passing through the poles and at right angles to the equator. A *meridian* is one-half of a meridian circle having its terminals at the poles.

D. *Parallels of Latitude.*—Parallels of latitude are circles drawn on the surface of the Earth, parallel to the equator. These circles diminish in size as we approach either pole.

E. *The Tropic of Cancer.*—The Tropic of Cancer is a parallel of latitude 23½° north of the equator. It marks the position farthest north of the equator reached by the vertical rays of the Sun. Its position is determined by the inclination of the Earth's axis.

F. *The Tropic of Capricorn.*—The Tropic of Capricorn is a parallel of latitude 23½° south of the equator. It marks the position farthest south of the equator reached by the vertical rays of the Sun. Its position is determined by the inclination of the Earth's axis.

G. *The Arctic and Antarctic Circles.*—These are parallels of latitude 23½°, respectively, from the north and south poles. They mark the positions touched by the tangential rays of the Sun on June 21 and December 21. Both circles are determined by the inclination of the Earth's axis.

IV. The Prime Meridian.—Owing to the fact that England played a very prominent part in the development of world trade, it became the custom of measuring distances

east or west of the meridian passing through Greenwich, a suburb of London, which contains a prominent astronomical observatory. This meridian is known as the *prime meridian.*

V. Longitude.—The longitude of a given place is its distance east or west of the prime meridian, measured in degrees along a parallel of latitude.

VI. The Relation between Time and Longitude.—Owing to the fact that the Earth rotates on its axis from west to east, the Sun *appears* to revolve around the Earth from east to west. Since there are 360 degrees in a circle and 24 hours in a day, the Sun travels toward the west 15 degrees every hour. We therefore say that 15 degrees of longitude are equal to 1 hour of time.

VII. Time on Board Ships.—As a general rule, ships carry one or more very accurate clocks (*chronometers*), set to Greenwich time. Several of the great naval radio stations, such as those at Arlington and Bordeaux, send out time signals which wireless operators on board ships pick up and use as a check on the chronometers. Local or *apparent* time, on board ships, is obtained by finding, by means of a sextant, the exact time when the Sun crosses the meridian. It is then apparent noon where the observer stands.

VIII. Method of Determining Longitude

A. With the aid of a sextant find when it is noon.

B. Find the difference between local time and Greenwich time, as indicated by the ship's chronometer.

C. Multiply the difference in hours by 15, since each difference of one hour in time corresponds to a difference of 15 degrees in longitude. The product is the number of degrees of longitude east or west of the prime meridian.

D. If Greenwich time is later than local time, the observer is in west longitude; if earlier, he is in east longitude.

Illustration.—Suppose that an observer finds by means of a sextant that it is local noon when the ship's chronometer indicates 2:12 p. m. Since Greenwich time is later than local time, he is at 33° west longitude ($15 \times 2\frac{12}{60} = 33°$).

IX. Latitude.—The latitude of a given place is its distance north or south of the equator, measured in degrees along a meridian.

X. Relation between the Pole Star and Latitude.—When one stands on the equator, the Pole Star is seen on the horizon. As one travels north, the Pole Star is seen rising toward the zenith. The altitude of the Pole Star above the horizon is the same as the latitude of an observer in the northern hemisphere.

XI. Sky Position.—The position of any body in the sky may be determined by reference to imaginary fixed lines. These lines include the *sky equator* and *hour circles* or *meridians.*

A. *Declination.*—The declination of a celestial body is its angular distance from the sky equator, measured along an hour circle.

B. *Altitude.*—The altitude of a celestial body is its angular distance above the horizon, measured along a great circle.

C. *Zenith Distance.*—The zenith distance of a celestial body is its angular distance from the zenith, measured along a great circle. It is equal to the difference between 90° and the altitude of the celestial body.

XII. The Nautical Almanac.—The *Nautical Almanac* is an annual publication of the United States Naval Observatory, published under the authority of the Secretary of the

Navy. Among other information of value to navigators, it contains tables showing the declination of the Sun for each day of the year.

XIII. Methods of Determining Latitude

A. Latitude may be determined *at night* by finding the altitude of the Pole Star with the aid of a sextant. This altitude is equal to the latitude of the observer's position on the Earth.

B. Latitude may be determined *during the day* as follows:

1. On the *dates of the equinoxes,* by finding the zenith distance of the Sun at local solar noon. This distance is equal to the latitude of the observer's position on the Earth.

2. On *other dates,* by using the formula $Z = L + D$.

> **Note 1.**—In the above formula, Z = zenith distance; L = latitude of observer; D = declination of the Sun, as given in the Nautical Almanac for the day on which the observation is made.
>
> **Note 2.**—In the northern hemisphere, use $+ D$ from September 23 to March 21 and $- D$ from March 21 to September 23. In the southern hemisphere reverse these signs.

XIV. Time Belts.—After railroads had become well-established and trade had grown to large proportions, a great deal of confusion and economic loss resulted from the fact that every town and city had its own local time. In many cases several different railroads entering the same city operated on different local times. To remedy this situation, the railroads adopted the present system of time belts in

1883 (Fig. 8). This system has been adopted all over the civilized world.

From Tarr and Von Engeln's NEW PHYSICAL GEOGRAPHY, *The Macmillan Co.*

FIG. 8.—TIME BELTS OF THE UNITED STATES

A. *Eastern Standard Time.*—Eastern standard time is based on the mean solar time of the meridian 75° west of Greenwich.

1. This time is used by a belt about 15° wide, extending from the Atlantic Coast to Toledo (Ohio) and Atlanta (Georgia).
2. In this belt, time is five hours earlier than Greenwich time. The belt includes New York City, Washington (D.C.), and Jacksonville (Florida).

B. *Central Standard Time.*—Central standard time is based on the mean solar time of the meridian 90° west of Greenwich.

1. This time is used by a belt extending from Toledo (Ohio) to Portal (North Dakota), and from Atlanta (Georgia) to San Angelo (Texas).

2. In this belt, time is six hours earlier than Greenwich time. The belt includes Chicago, St. Louis, and New Orleans.

C. *Mountain Standard Time.*—Mountain standard time is based on the mean solar time of the meridian 105° west of Greenwich.

1. This time is used by the Rocky Mountain states. It is seven hours earlier than Greenwich time.
2. In this belt are included Helena (Montana), Denver (Colorado), and Phoenix (Arizona).

D. *Pacific Standard Time.*—Pacific standard time is based on the mean solar time of the meridian 120° west of Greenwich.

1. This time is used by the Pacific coast states.
2. In this belt, time is eight hours earlier than Greenwich time. The belt includes Portland (Oregon), and San Francisco and Los Angeles (California).

XV. Astronomical Days

A. *The Siderial Day.*—A siderial day is the time it takes the Earth to make one complete rotation on its axis. It is determined by the time that elapses between the passage of a given star across a meridian and the next passage of the same star across the same meridian.

B. *The Solar Day.*—A solar day is the time that elapses between two successive crossings of a given meridian by the Sun. To complete one solar day the Earth must turn 361° on its axis, a little more than one complete rotation.

C. *The Mean Solar Day.*—Since the apparent motion of the Sun is a little faster when it is near perihelion than when near aphelion, solar days are not

all of the same length. For purposes of keeping time, the average length of all solar days is called a *mean solar day*. Time based on the mean solar day is called *mean solar time*. It is the time kept by watches and clocks.

D. *The Civil Day.*—The civil day is the ordinary business and legal day. It begins at midnight, ends at midnight, and is based on mean solar time. It originates at the 180th meridian and travels around the world from east to west.

XVI. The International Date Line.—When westward-going ships cross the 180th meridian, the name of the day is changed to a day forward; when going eastward, it is changed to a day backward. The 180th meridian is therefore called the international date line, except where offsets are made to avoid confusion of dates. Going south along the 180th meridian, the date line turns eastward to pass through Behring Strait, then westward to pass around the Aleutian Islands. Returning, it continues along the 180th meridian until it turns eastward to avoid the Fiji Islands and New Zealand. It then finally returns to, and continues along, the 180th meridian.

XVII. The Gregorian Calendar.—The Gregorian calendar is the one in use at the present time. It was preceded by the *Julian* calendar, which considered a year as being 365¼ days long. The extra one-quarter day was taken care of by adding a day every fourth year (*leap year*).

Note.—The Julian year was 11.2 minutes too long. To correct this error, Pope Gregory XIII decreed in 1582 that ten days be stricken from the calendar, and that thereafter the years that are divisible by 100 should not be considered leap years unless they are also divisible by 400. Thus the years 1800 and 1900 are not leap years, but the years 1600 and 2000 are.

QUESTIONS

1. (a) Define: *latitude; longitude.* (b) Compare the lengths of latitude and longitude degrees as one travels from the equator to the north pole.

2. What causes a difference in the lengths of latitude and longitude degrees as one travels from north to south?

3. What determines the location of (a) the equator; (b) the Tropics of Cancer and Capricorn; (c) the Arctic and Antarctic Circles?

4. Show that there is an analogy between locating a house in a city by means of numbered streets and avenues and locating a ship at sea by means of latitude and longitude.

5. How does the navigating officer of a ship determine his latitude and longitude from observations of the Sun?

6. How does the navigating officer of a ship determine his position if there is continued cloudy weather?

7. Is the Sun a reliable time keeper? Explain.

8. Do the shortest shadows occur at the exact noon as indicated by an accurate railroad watch? Explain.

9. Assuming that New York banking hours are between 9 a. m. and 3 p. m., between what hours would a New York banker telephone to (a) a London banker; (b) a Los Angeles banker?

10. Through how many degrees does the Earth revolve during (a) a solar day; (b) a lunar day; (c) a siderial day? Explain.

11. In sailing from San Francisco to Melbourne, does one repeat or omit a day? Explain.

12. If it is 9:30 a. m. by the ship's chronometer when it is solar noon on the ship, what is the ship's longitude?

13. If the Sun's zenith distance at noon is 15°*S* on a day when the Sun's declination is 18°*N*, what is the ship's latitude?

14. If the Sun's zenith distance at noon is 15°*N* on a day when the Sun's declination is 20°*N*, what is the ship's latitude?

CHAPTER IV

THE SOLAR SYSTEM

I. The Solar System.—The solar system consists of the Sun and the bodies that revolve around it. These bodies are

A. The planets with their satellites.
B. The planetoids.
C. Some comets.
D. Some meteors.

II. The Sun.—The Sun is a huge ball of incandescent gas and liquid, located at the center of the solar system. It holds the rest of the solar system together by means of its powerful gravitational attraction. It is the direct cause of winds and rain, and is the source of heat and light that make life possible on the Earth and perhaps also on other planets.

A. *Diameter.*—The diameter of the Sun is 866,000 miles—more than one hundred times the diameter of the Earth.

B. *Density.*—The Sun is 1.4 times as heavy as a sphere of water of the same size. The density of the Sun is therefore much less than that of the Earth, due doubtless to its very high temperature.

III. The Photosphere.—The photosphere is a layer of heavy incandescent vapor in which metals are believed to predominate. It is the chief source of the light and heat that emanate from the Sun.

IV. Sun Spots.—Dark, crater-like depressions, called *sun spots,* may be seen in the photosphere. These spots are dark only by comparison with the very bright surface adjacent to them. Sun spots gradually increase and decrease

in activity. They reach their maximum activity once in eleven years.

V. The Chromosphere.—The chromosphere is a deep layer of incandescent gas outside the photosphere. During a total eclipse of the Sun it is seen as a brilliant scarlet ring, from which prominences like tongues of flame shoot out for many thousands of miles.

VI. The Corona.—The corona is a halo of light seen around the Sun during a total eclipse. Streamers of light extend from it for millions of miles. It is probably caused by the reflection of light from dust particles that have been thrown out from the Sun by violent eruptions.

VII. Elements in the Sun.—When light from the photosphere passes through the rarefied gases of the chromosphere, it loses those wave lengths which each of the rarefied gases would emit if it were alone. Spectroscopic examination of this light indicates that iron, gold, carbon, nickel, silver, and many other elements found in the Earth exist in the form of incandescent vapors in the Sun's atmosphere.

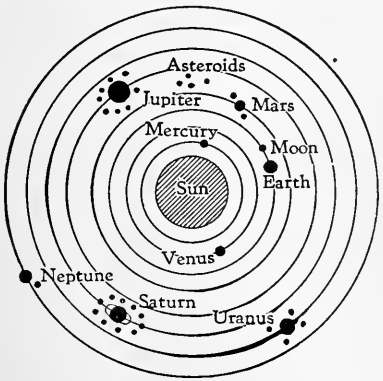


FIG. 9.—THE PLANETS WITH THEIR SATELLITES

VIII. The Planets.—The planets are large spherical masses resembling the Earth in composition and movements. Each planet rotates on its axis and revolves around the Sun. Several of the planets have one or more satellites revolving about them. **Jupiter,** the largest of the planets, has a diameter more than ten times that of the Earth. The planet **Neptune** is so far away that light on its surface looks like dim twilight on the Earth. Its orbit is so large that a single year on that planet is longer than a lifetime for one of us.

IX. Comparison of the Planets

Planet	Diameter in Miles	Distance from the Sun in Millions of Miles	Time of Revolution in Years
Mercury	2,700	36	0.24
Venus	7,800	67	0.62
Earth	7,926	93	1.00
Mars	4,300	141	1.88
Jupiter	87,000	483	12.00
Saturn	72,000	886	29.00
Uranus	35,000	1,782	84.00
Neptune	32,000	2,792	165.00

X. Satellites.—A satellite is a body which revolves around a planet just as a planet revolves around the Sun. **Mercury** and **Venus** have no satellites; other planets have from one to ten.

XI. Planetoids.—The planetoids, sometimes called *asteroids,* are a group of bodies revolving around the Sun in an orbit lying between Mars and Jupiter. They are very small in comparison with the planets, and are believed to be either the fragments of a disrupted planet or fragments which will eventually form a planet.

XII. Comets.—Comets are bodies having a small mass and an enormous volume. They either revolve around the Sun in very long, elliptical orbits, or pay us a visit from outer space, escape from the attraction of the Sun, and sail away again into space. A typical comet consists of a head and a tail.

A. In the center of the head is a nucleus composed of comparatively dense material believed to consist of bits of gravel-like rock. This nucleus may be as large as our Earth.

B. The nucleus is surrounded by a faintly luminous region called the *coma.* The coma, which may be

as large as the Sun, is believed to be composed of gaseous material, or possibly of small, dust-like particles.

C. The tail is usually millions of miles long. It is composed of highly attenuated matter, and always points away from the Sun.

Note.—Comets are self-luminous, but shine also by reflected light.

XIII. Meteors.—A meteor, or *shooting star,* is a bit of rock which has entered our atmosphere with terrific speed.

A. Friction with the air causes meteors to become white-hot, and they therefore leave a trail of molten material behind them. Only the larger masses reach the solid earth before being dissipated into dust. These are known as *meteorites.*

B. Chemical examination of meteorites shows that while many of them are composed of ordinary rock material, others are largely alloys of iron and nickel.

C. The fact that an enormous number of meteors reach the Earth every year is evidence in favor of the theory that the Earth is growing rather than shrinking.

XIV. Origin of the Solar System.—It has long been noticed that the planets spin on their axes and revolve around the Sun in the same direction, and that their orbits are nearly in the same plane. These facts point to a common origin, and many theories have been proposed to account for this origin. The *Nebular* and *Planetesimal Hypotheses* have exerted a great influence on our thinking.

XV. The Nebular Hypothesis

A. The entire solar system was at one time a vast cloud of very hot gaseous material, called a *nebula.*

B. As this nebula cooled and contracted, it acquired

a rotary motion which caused it to break up into rings.

C. These rings broke, and, owing to gravity, the material of each became concentrated and formed a planet.

D. The planets, in turn, cooled, contracted, and acquired a rotary motion. They then broke up into rings which became satellites.

E. The larger planets, owing to their greater gravitational attraction, have been able to retain gases as their atmospheres. The two smallest planets and the satellites have lost their atmospheres.

F. On the Earth, and possibly on some other planets, water vapor condensed and fell as rain, finally filling the depressions and thus forming the oceans.

XVI. The Planetesimal Hypothesis

A. The solar system was at one time a vast, cold nebula, spiral in form. It contained knots, or *nuclei,* and had a rotary motion.

B. The nuclei were denser portions of the nebula. The largest nucleus at the center became our Sun. Other large nuclei developed into planets; and those smaller nuclei which were near large ones developed into satellites of the planets.

C. The nuclei were surrounded by a nebulous haze. This haze contained molecules of gas and also small solid and liquid particles, called *planetesimals.*

D. The Sun, planets and satellites grew by the infall of planetesimals. Compression made the temperature rise.

E. As the temperature of the Earth rose, gases were forced out of its interior and an atmosphere was formed. It is believed that the Earth was unable to retain its atmosphere until it had become considerably larger than our Moon is now.

F. The water vapor in the Earth's atmosphere finally formed rain. Then began the work of erosion (page 130), which has so greatly modified the surface features of the Earth.

XVII. Evidences in Favor of the Nebular Hypothesis

A. The Sun and the planets spin on their axes in the same direction. The planets and satellites revolve in the same direction, and their orbits are in nearly the same plane.

B. Nebulae of the ring type can be seen with the aid of a telescope.

C. The Sun is radiating tremendous quantities of heat. It seems reasonable to assume that it was at one time very much larger and hotter than it is now.

D. The spectroscope shows that the Sun is composed of the same elements as those found on the Earth. It is reasonable to assume that the bodies forming the rest of the solar system are composed of similar elements, thus pointing to a common origin.

> **Note.**—While there are a few direct evidences in favor of this hypothesis, there are also strong arguments against its acceptance. Thus, mathematical calculations prove that the rings would not have formed in such a way as to cause the present distribution of the planets, and the Sun has not shrunk appreciably since the first accurate measurements of its diameter were made.

XVIII. Evidences in Favor of the Planetesimal Hypothesis

A. Many nebulae of the spiral type in various stages of development can be seen with the aid of a telescope.

B. A tremendous number of meteors reaches the Earth

every year. Since the Earth is not throwing off any material, it must be growing.

C. Chemical analysis of these meteors shows that while many are composed of rocky material, a great many others are composed of a nearly pure iron-nickel alloy. The density of the Earth, radio and earthquake transmission, and the fact that the Earth behaves like a huge magnet seem to indicate that the Earth might have been built by the accretion of meteors.

D. The principal gases in the Earth's atmosphere (nitrogen, oxygen, and carbon dioxide) and the elements composing water (hydrogen and oxygen) have been found occluded in meteorites.

Note.—The Planetesimal Hypothesis is more widely accepted by scientists than the older Nebular Hypothesis.

QUESTIONS

1. Distinguish between (a) *planets* and *stars;* (b) *stars* and *shooting stars.*

2. Compare the diameter of the Sun with the diameter of the Moon's orbit.

3. Why do some planets have an atmosphere while others do not?

4. (a) What is the *Nebular Hypothesis?* (b) Discuss the evidences in favor of this hypothesis.

5. (a) What is the *Planetesimal Hypothesis?* (b) Discuss the evidences in favor of this hypothesis.

6. If the Earth should pass through the tail of a comet, would there be danger of suffocation from poisonous gases?

7. Why are some comets considered to be members of the solar system while others are not?

8. Is there any evidence that Mars or Venus is inhabited?

9. Which of the two planets, Mars or Venus, most closely resembles the Earth in (a) diameter; (b) length of day and night; (c) density of atmosphere?

CHAPTER V

THE MOON

I. General Characteristics.—The Moon is a large spherical mass of rock material revolving around the Earth as a satellite. Its surface is broken up by rugged mountains resembling extinct volcanoes. Owing to the fact that the Moon

From Tarr and Von Engeln's New Physical Geography, *The Macmillan Co.*

Fig. 10.—Relative Sizes of the Earth and the Moon

has no atmosphere and no moisture, the ruggedness of its surface has never been softened by erosion as has the surface of the Earth.

II. Important Facts about the Moon

A. The diameter of the Moon is 2,163 miles—a little more than one-quarter of the Earth's diameter.

B. The distance of the Moon from the Earth varies from 220,000 to 253,000 miles, averaging about 240,000 miles.

C. The Moon makes one complete revolution about the Earth in 27⅓ days. The *apparent* time, however, from full moon to full moon, is 29½ days.

D. The Moon rises, on the average, about 50 minutes later each day.

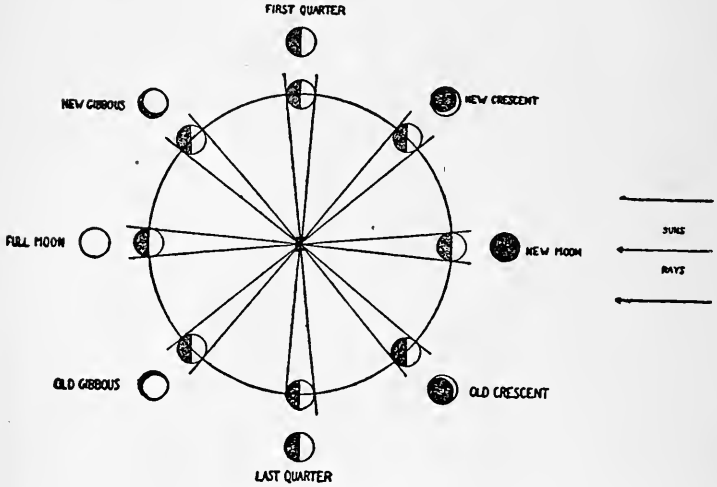
E. The Moon rotates once on its axis while it makes one complete revolution around the Earth. It therefore always presents the same face toward the Earth. This accounts for the fact that we have never seen the other side of the Moon.

III. Phases of the Moon.—The Moon shines entirely by reflected sunlight. Since only that portion of the Moon which faces the Sun is illuminated, varying amounts of the illuminated portion are visible as the Moon revolves around the Earth. This fact gives rise to the following phases of the Moon (Fig. 11):

A. *New Moon.*—When the Sun and the Moon are on the same side of the Earth, the phase is called *new moon.* The dark side of the Moon faces the Earth and is therefore invisible. A few days later it is seen as a thin crescent early in the evening. The new moon rises at sunrise and sets at sunset.

B. *First Quarter.*—About one week after *new moon,* one-half of the illuminated half of the Moon becomes visible. This phase is called *first quarter.* The Moon then rises at noon and sets at midnight.

C. *Full Moon.*—About two weeks after *new moon,* the entire illuminated half of the Moon becomes visible. This phase is called *full moon.* The Moon is then on the side of the Earth which is turned away from the Sun. The full moon rises at sunset and sets at sunrise.



From NEW PHYSIOGRAPHY, *D. C. Heath & Co.*

FIG. 11.—PHASES OF THE MOON

D. *Third Quarter.*—Three weeks after *new moon,* the appearance of the Moon is the same as it was during *first quarter.* Third quarter moon rises at midnight and sets at noon.

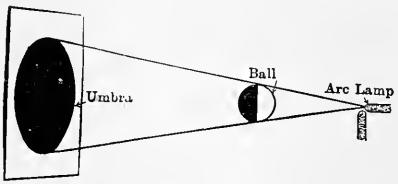


FIG. 12.—SHADOW CAST BY A SMALL SOURCE OF LIGHT

IV. Shadows.—When an opaque body is placed between a source of light and a surface, such as a wall or a sidewalk, the space

is darkened on the side of the opaque body away from the source of light. This darkened space is called the *shadow* of the body.

A. *Umbra.*—When the source of light is exceedingly small, the shadow is uniformly dark and is called the *umbra* (Fig. 12).

B. *Penumbra.*—When the source of light is comparatively large, a lighter area surrounds the umbra. This partially lighted portion of a shadow is called the *penumbra* (Fig. 13). The penumbra of a shadow gradually shades off from dark to light.

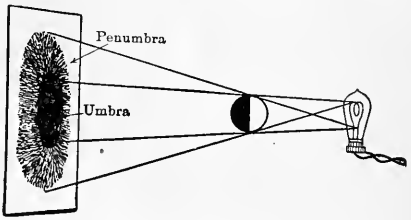
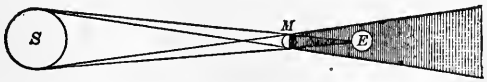


FIG. 13.—SHADOW CAST BY A BROAD SOURCE OF LIGHT

V. Eclipses.—The planets and satellites are accompanied by long, cone-shaped umbras, or dark shadows. The shadow of the Earth is about 866,000 miles long, and that of the Moon is about 233,000 miles.



From PHYSICS *by Fuller, Brownlee and Baker, Allyn & Bacon.*

FIG. 14.—ECLIPSE OF THE SUN

A. *Eclipse of the Sun.*—A total eclipse of the Sun takes place when the Moon is exactly between the Earth and the Sun (Fig. 14). The tip end of the Moon's shadow then reaches the Earth. In order to see an eclipse of the Sun, one must stand inside

of the dark circle formed by this shadow. Outside this circle, but inside the penumbra, the eclipse is *partial.*

From PHYSICS *by Fuller, Brownlee and Baker, Allyn & Bacon.*

FIG. 15.—ANNULAR ECLIPSE OF THE SUN

B. *Annular Eclipse of the Sun.*—When the Moon is between the Earth and the Sun, and the Moon is so far away that its shadow does not quite reach the Earth (Fig. 15), an *annular eclipse* is formed. The Moon does not then quite cover the Sun, and a bright ring can therefore be seen around the dark surface of the Moon.

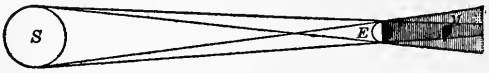


FIG. 16.—ECLIPSE OF THE MOON

C. *Eclipse of the Moon.*—A total eclipse of the Moon takes place when it is on the opposite side of the Earth from the Sun and passes through the Earth's shadow (Fig. 16). If the Moon passes slightly north or south of a straight line from the Sun through the Earth, it only partly enters the Earth's shadow and a *partial eclipse* occurs.

D. *Number of Eclipses in One Year.*—Since the Moon's orbit makes an angle of 5° with the Earth's orbit, eclipses occur only when the Moon crosses the Earth's orbit at the time when it is exactly in line with the Sun and the Earth. This occurs at irregular intervals, but at times that astronomers

are able to calculate. There are always two, and there may be four, eclipses of the Sun in one year. The maximum number of eclipses of the Moon in one year is three.

QUESTIONS

1. Explain why we have never seen the other side of the Moon.

2. (a) What is meant by the *phases* of the Moon? (b) How long a time is required for the Moon to complete its cycle of phases? (c) Why is this period longer than the time required for a complete revolution of the Moon?

3. What are the relative positions of the Sun, Moon and Earth, (a) at new moon; (b) at full moon; (c) at third quarter?

4. (a) Distinguish between *umbra* and *penumbra.* (b) Compare the length of the Moon's umbra with the distance of the Moon from the Earth.

5. (a) Distinguish between the *waxing* and the *waning* of the Moon. (b) Between what phases is the Moon waxing? Waning?

6. What causes a total eclipse of (a) the Moon; (b) the Sun?

7. Is it possible to have a total eclipse of the Moon at (a) full moon; (b) new moon?

8. Explain why we do not always have an eclipse of the Moon at full moon.

CHAPTER VI

THE EARTH AS A MAGNET

I. Natural Magnets.—Some iron ores, such as lodestone (*magnetite*), possess the property of attracting small bits of iron. These ores are called *natural magnets.*

> **Note.**—The terms *magnet* and *magnetite* are derived from Magnesia, a city in Asia Minor, where lodestone was first discovered by the ancient Greeks.

II. Artificial Magnets.—When a piece of iron or steel is rubbed with lodestone, it acquires the power of attracting and holding iron filings, nails, and other bits of iron or steel. It retains its magnetism indefinitely and is called an *artificial magnet.*

III. Magnetic Poles

A. If we lay a sheet of paper on a bar magnet and sprinkle iron filings over it, we find that the filings cling most strongly at or near the *ends* of the magnet. The ends of a magnet at which the attraction is greatest are called the *poles* of the magnet.

B. If we suspend a bar magnet so that it is free to swing in a horizontal plane, it always comes to rest in a north and south direction. The end of the magnet which points north is called the *north pole* of the magnet; the other end is called the *south pole.*

IV. Mutual Action of Magnetic Poles.—Suspend a steel bar magnet by a thread so that it is free to swing in a horizontal plane. Bring the north pole of another bar magnet near to the north pole of the suspended magnet. *The magnets repel each other.* Bring the south pole of the second magnet near to the north pole of the suspended magnet. *The magnets attract each other.*

V. Law of Magnetic Action

A. Like magnetic poles repel each other.

B. Unlike magnetic poles attract each other.

VI. Magnetic Field.—The space surrounding a magnet in which the magnet exerts its influence is called its *magnetic field.* If a piece of cardboard is placed over a steel magnet and iron filings sprinkled over it, the filings arrange themselves in lines running from one pole of the magnet to the other and serve to visualize the magnetic field.

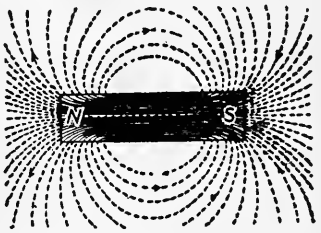


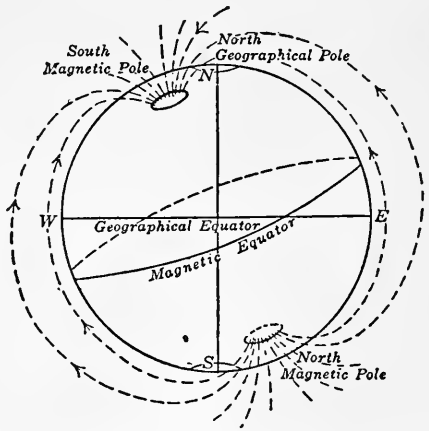
FIG. 17.—MAGNETIC FIELD AROUND A BAR MAGNET

VII. Magnetic Lines of Force.—A magnetic line of force is the path along which a freely-moving isolated north pole would move, urged by the attractions and repulsions of the magnetic poles in its vicinity. Magnetic lines of force may be traced by moving a small magnetic compass in a magnetic field.

VIII. The Magnetic Compass.—The magnetic compass is a device used in navigation and surveying to determine directions. It consists of a magnetic needle, pivoted so that it can swing freely in a horizontal plane.

IX. The Earth a Huge Magnet.—The Earth is a huge magnet having a north and a south pole.

A. *The South Magnetic Pole.*—Since the north pole of a magnet points to the north pole of the Earth, the magnetic pole in the far north is a *south* magnetic pole. It is located northwest of Hudson Bay, about 73° 31′ N latitude and 98° 48′ W longitude.



From Practical Physics *by Black and Davis, The Macmillan Co.*

Fig. 18.—The Earth's Magnetic Field

B. *The North Magnetic Pole.*—This pole is located in the Antarctic region, almost opposite to the south magnetic pole.

> **Note.**—The magnetic field of the Earth consists of magnetic lines of force diverging from the south magnetic pole and converging again at the north magnetic pole.

X. Declination of the Compass.—The compass needle does not everywhere point to the true north. The number of degrees that the magnetic compass points east or west of the true north is called the *magnetic declination* of the compass.

XI. Isogonic and Agonic Lines.—Since the compass needle does not everywhere point to the true north, the entire surface of the Earth has been charted to show the magnetic declination of the compass. The lines on this chart are called *isogonic* and *agonic* lines.

A. *Isogonic Lines* are lines on the chart which connect places having the same magnetic declination.

B. *Agonic Lines* are lines on the chart which connect places where the compass points to the true north.

XII. The Mariners' Compass.—The mariners' compass consists of a cardboard disc to the underside of which are fastened several magnetic needles in parallel positions. The disc is marked with the thirty-two points of the compass and is suspended on a jewelled point. The basin which holds this disc is suspended on gimbals, so that, as the ship rolls and pitches, the disc remains in a horizontal position.

XIII. Other Compasses.—Compasses have been devised to overcome the defects and limitations of the magnetic compass.

A. *The Gyro-Compass.*—This device consists of two heavy wheels rotating in opposite directions at great speed. It is a modified gyroscope, and is operated by means of an electric motor. While rotating, the axis maintains parallelism.

B. *The Earth-Inductor Compass.*—This compass is used in aeroplanes.

1. It consists essentially of a sensitive galvanometer and a coil of wire arranged to rotate about an axis. The coil is made to rotate by a small propeller, which acts like a windmill.
2. When the coil rotates, it cuts across lines of force of the Earth's magnetic field and therefore generates a weak electric current.

3. As the angle between the axis of the coil and the direction of the lines of force changes, the amount of current developed varies. The reading of the galvanometer therefore indicates directions.

QUESTIONS

1. Distinguish between *natural magnets* and *artificial magnets.*

2. Will a magnet attract (a) an aluminum saucepan; (b) a tin dipper; (c) a sheet of gold foil; (d) a flatiron?

3. (a) What is meant by the *poles* of a magnet? (b) State the law of magnetic action.

4. (a) Define: *magnetic field; magnetic line of force.* (b) Describe an experiment showing that lines of force surround a magnet.

5. (a) Give two reasons why the Earth may be regarded as a huge magnet. (b) Mention two uses of the magnetic needle. (c) State why the magnetic needle does not everywhere point due north.

6. Is the blue or the white end of a magnetic compass needle the north-seeking pole?

7. (a) What evidence is there that the interior of the Earth is largely composed of iron? (b) Could the Earth act as a huge magnet if it were not largely composed of iron?

8. (a) What is meant by the *magnetic declination* of the compass? (b) Define: *isogonic lines; agonic lines.* Explain their value to navigators and surveyors.

9. (a) What are the defects of the magnetic compass? (b) What compasses have been devised to overcome these defects?

CHAPTER VII

STARS AND CONSTELLATIONS

I. Stars.—A star is a distant sun. It may resemble our own Sun in being a hot mass of incandescent liquid or gaseous material, or it may be a distant sun which was incandescent at one time, but has since cooled down to a dark spherical mass.

A. Some stars are very much larger and hotter than our own Sun. It is highly probable that many, if not all, are accompanied by planets.

B. Stars vary in brightness, not only because of their size and temperature, but also because of their distance from the Earth.

C. According to their degree of brightness, stars are classified as stars of the *first magnitude, second magnitude,* etc. The faintest stars visible without the aid of a telescope are stars of about the sixth magnitude.

II. The Nearest Fixed Star.—The nearest fixed star, *Alpha Centauri,* is about 20,000 times as far from the Earth as the Sun. While it takes only 8⅓ minutes for light to reach us from the Sun, it requires 4.4 years for light to come to us from *Alpha Centauri.*

III. The Brightest Star.—*Sirius,* the brightest star in the sky, is a member of the constellation *Canis Major. Venus* is somewhat brighter than *Sirius,* but it is a planet rather than a star.

IV. The Pole Star.—If a photographic plate is exposed for several hours at night toward the north, it shows, when developed, streaks of light forming arcs of concentric circles.

A. The star nearest to the common center of these circles is the *Pole Star.*

B. The center of these circles is the *sky pole,* or the point toward which the Earth's axis points.

C. The Pole Star is about 1.5° from the sky pole and appears to revolve around it once in 24 hours. It is a very useful sky mark in determining direction and latitude.

V. Constellations.—A constellation is a group of stars to which a definite name has been given. In many cases there is a resemblance in the pattern of the constellation to the name it bears, such as the *Big Dipper* and the *Corona.* Many constellations bear the names of mythological characters, with whom the ancients peopled the skies.

VI. Familiar Constellations

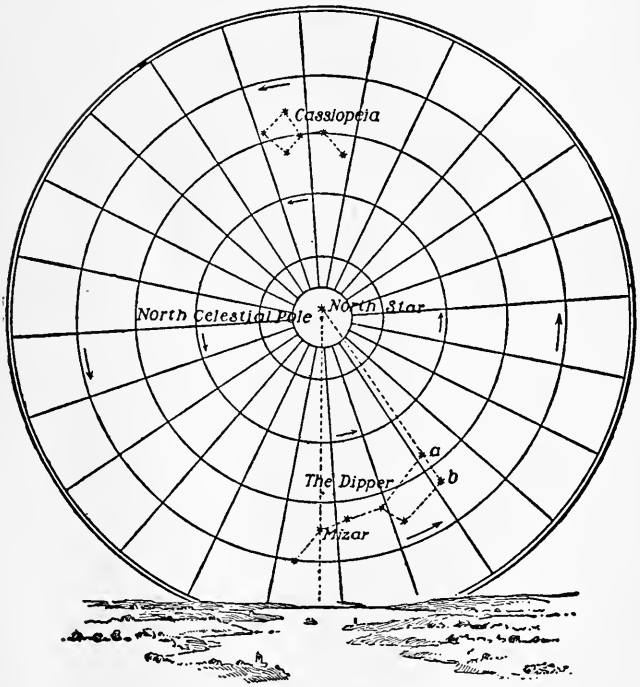
A. *The Little Dipper (Ursa Minor).*—This constellation may be readily located from the fact that the Pole Star is at the end of the handle. The seven stars constituting this constellation are not as brilliant as those of the *Big Dipper.*

B. *The Big Dipper (Ursa Major).*—The seven bright stars which form the outline of the *Big Dipper* are very conspicuous in the northern part of the sky. The two stars at the end of the bowl point toward the Pole Star, and are therefore commonly called *pointers.*

C. *Cassiopeia.*—This constellation is on the opposite side of the Pole Star from the *Big Dipper* and

about the same distance from it. It is easily recognized from its resemblance to the letter *W*.

Note.—The above-mentioned constellations are grouped around the Pole Star and are visible to residents of the Northern Hemisphere at all seasons of the year.



From New Physiography, *D. C. Heath & Co.*

Fig. 19.—Position of the Big Dipper when the Pole Star is Exactly in the North

D. *Orion.*—This constellation is located south of the sky equator and is visible in the United States only during the winter months. When viewed through

a telescope, one of the stars constituting *Orion* is seen to be composed of a cluster of stars. This constellation contains also a *nebula.*

VII. Universes.—Our universe consists of an enormous number of stars, rotating about a central point, and grouped in a disc- or lens-shaped mass. When looking toward the *Milky Way,* we are looking along the long diameter of the system. Other universes, sometimes called *island universes,* can be seen with the aid of a powerful telescope at great distances from our own.

VIII. True North and South Line.—When *Mizar,* the brilliant star in the bend of the handle of the *Big Dipper,* is exactly above or below the Pole Star (as determined by means of a plumb line), then a line aiming at the Pole Star is a true north and south line.

QUESTIONS

1. (a) What is a star? (b) A constellation? (c) A universe?
2. (a) Which is the nearest star (other than our own Sun)? (b) Which is the brightest star?
3. Compare the importance of a knowledge of the stars and constellations to a dweller in the desert, a navigator, and a dweller in a large city.
4. Explain how a surveyor can determine a true north and south line.
5. Name three important constellations grouped around the Pole Star.

CHAPTER VIII

THE ATMOSPHERE

I. The Atmosphere.—The atmosphere is an envelope of gas surrounding the solid and liquid portions of the Earth. It extends more than two hundred miles above sea level and penetrates the soil and the waters of rivers, lakes, and oceans.

II. Composition of the Air.—Air is a mixture of gases, the most important of which are

Nitrogen, 78%	Carbon dioxide, 0.04%
Oxygen, 21%	Rare gases, about 1%

III. Nitrogen.—Nitrogen, in the *free* state, constitutes about four-fifths of the volume of the atmosphere. This gas is colorless, odorless, and tasteless. It is very inactive chemically, does not burn, and does not support combustion. It is an essential constituent of all living things. Its function in the atmosphere is to dilute the oxygen.

IV. Fixation of Atmospheric Nitrogen.—The process of converting the nitrogen of the air into useful compounds is called *fixation of atmospheric nitrogen.* This process is accomplished in a number of ways, the usual products being ammonia, nitric acid, and nitrates.

A. *Fixation by Nature*

1. Certain *bacteria* which thrive on the roots of leguminous plants, such as peas, beans, clover, alfalfa, etc., have the power of converting atmospheric nitrogen into nitrates.

2. *Lightning* causes the direct union of nitrogen and oxygen, to a small extent, forming nitric oxide. By a series of chemical reactions this nitric oxide is converted into nitric acid, which combines with materials in the soil, forming nitrates.

B. *Fixation by Man*

1. *Action of the Electric Arc*

(a) This corresponds to the action of lightning. The chemical reactions involved are the same.

(b) The nitric acid is neutralized by slaked lime and the calcium nitrate thus formed is used as a fertilizer.

2. *The Cyanamide Process*

(a) Nitrogen, obtained from liquid air by fractional distillation, is passed over hot calcium carbide, forming calcium cyanamide.

(b) By a series of chemical reactions the calcium cyanamide is converted into nitric acid. The nitric acid is then combined with ammonia, forming ammonium nitrate.

Note.—The U. S. Nitrate Plant No. 2, at Muscle Shoals, Alabama, is equipped for the cyanamide process.

V. Nitrate Deposits

A. *Guano.*—In many parts of the world, particularly on the South Sea Islands, birds have left rich accumulations of guano containing a large percentage of nitrates. Guano is an excellent fertilizer and has been imported for this purpose in large quantities. These deposits are now nearly exhausted.

B. *Chile Saltpeter.*—An enormous deposit of Chile

saltpeter (*sodium nitrate*) is found along the western slopes of the Andes Mountains in Chile. These deposits are believed to be of organic origin, or perhaps represent atmospheric nitrogen which was "fixed" in some remote geological period. Large quantities of this material are imported into the United States for use as fertilizer and also for chemical manufacturing purposes.

VI. Oxygen.—Oxygen, in the *free* state, constitutes about one-fifth of the volume of the atmosphere. It is a colorless, odorless, and tasteless gas. It supports combustion and is otherwise very active chemically. Many substances which do not burn in air burn vigorously in pure oxygen.

VII. Oxidation.—Oxidation is the chemical union of a substance with oxygen.

A. *Combustion.*—Combustion is a rapid oxidation accompanied by heat and light. The burning of coal in a furnace or of gasoline in the engine of an automobile are examples.

B. *Rusting.*—Rusting is the slow oxidation of a metal, not accompanied by light or *noticeable* heat.

C. *Erosion.*—Oxygen helps to disintegrate rocks and therefore aids the process of erosion.

D. *Respiration.*—Slow oxidation takes place in the living cells of all plants and animals. This process furnishes the organism with heat and energy, and helps eliminate waste products.

VIII. Carbon Dioxide.—Carbon dioxide is a colorless, odorless, and tasteless gas. It neither burns nor supports combustion. Its chief sources are respiration, the decay of animal and vegetable matter, and the combustion of fuels.

Note.—Carbon dioxide can be readily distinguished from nitrogen by the fact that it turns lime water milky, while nitrogen does not.

IX. Uses of Carbon Dioxide

A. *Food for Plants.*—In the process of *photosynthesis*, carbon dioxide unites with water, forming starch. This action takes place in the leaves of green plants and requires the presence of *chlorophyll* to act as a catalytic agent, and of *sunlight* to furnish the energy. Oxygen is given off as a by-product in this process.

B. *Retention of Heat.*—Carbon dioxide acts like the glass of a greenhouse in that it admits sunlight, but tends to retain the heat radiated by the Earth.

C. *Erosion.*—Carbon dioxide unites with water, forming carbonic acid. This weak acid acts slowly on rocks, causing them to disintegrate. It acts fairly rapidly on limestone and is responsible for the formation of limestone caves.

X. Water Vapor.—Water vapor is not considered to be a constituent of the atmosphere, but rather a visitor from lakes and oceans. The presence of water vapor in the air makes breathing comfortable and provides for the formation of rain, which plays a very important part in making the surface of the earth inhabitable. Rain is chiefly responsible for the present appearance of the Earth's surface, since running water is the chief agent of erosion.

XI. Dust.—There is always more or less dust in the air. This dust is of two kinds: *organic* and *inorganic.*

A. *Organic Dust.*—Organic dust is composed partly of fragments of dead organic material, and partly of living germs and the spores of molds and fungi. We realize that germs and spores are present practically everywhere when we remember that fermentation and decay cannot take place without the presence of germs, and molds cannot form without spores.

B. *Inorganic Dust.*—Inorganic dust is composed of rock fragments. Winds sweeping over dry earth pick up and carry dust; volcanoes throw dust up into the air. The presence of inorganic dust everywhere is shown by the necessity for frequently dusting articles of furniture even on ships at sea. Explorers report finding a residue of dust after melting snow in the Arctic regions.

XII. Effects of Dust in the Air

A. *Causes the diffusion of light.*—Rooms which do not receive direct sunlight would be much darker than they are if there were no dust particles in the air to scatter the light.

B. *Causes the sky to appear blue and the setting Sun to appear red.*

1. Dust particles floating in the air reflect more blue light than red, and transmit more red light than blue. This occurs because waves producing red light are nearly twice as wide as waves producing blue, and many particles of dust that are large enough to stop "blue" waves are not large enough to stop "red" waves.

2. When looking directly toward the Sun at sunset, our eyes receive light that has travelled a long distance through dust-laden air and much of the blue light has been eliminated. The setting Sun therefore appears red.

3. On the other hand, when looking at the open sky *away* from the Sun, our eyes receive blue light reflected from countless dust particles, and the sky therefore appears blue.

XIII. Functions of the Atmosphere

A. Maintains a range of temperature best suitable for life by tempering the incoming heat from the Sun and by lessening the escape of heat from the Earth by radiation.
B. Makes combustion and respiration possible.
C. Transmits sound waves.
D. Diffuses light, so that shaded places are not entirely dark.
E. Aids erosion.
F. Exerts a buoyant force, thus enabling balloons to rise.
G. Offers resistance, thus enabling birds and aeroplanes to fly.
H. Gives rise to convection currents, thus causing

1. Winds, with the resulting waves and ocean currents.
2. The distribution of moisture in the form of rain and snow.
3. The distribution of the pollen and seeds of plants.
4. The propulsion of sailing vessels and windmills.

QUESTIONS

1. (a) Name the three most important constituents of the atmosphere. (b) What are the functions of each of these constituents?

2. (a) What is meant by *fixation of nitrogen?* (b) What is the importance of "fixed" nitrogen to agriculture?

3. Describe two methods employed for "fixing" atmospheric nitrogen.

4. (a) What is the function of water vapor in the air? (b) Is water vapor a constituent of the air?

5. What properties of air are made use of when, (a) birds fly; (b) balloons rise; (c) ships sail; (d) automobile tires are inflated; (e) pneumatic tools are operated?

6. (a) Name the two kinds of dust found in the air. (b) Describe the effects produced by dust in the air.

7. Explain why the setting Sun appears red and the open sky appears blue?

8. (a) To what is the corrosive effect of the air due? (b) Describe three methods employed to protect iron from the corrosive effect of the air.

9. Explain the origin of the atmosphere according to (a) the Nebular Hypothesis; (b) the Planetesimal Hypothesis.

10. Describe the cycle by which oxygen is taken from the air and is finally returned as free oxygen.

CHAPTER IX

HEAT AND INSOLATION

I. Nature of Heat.—All matter is composed of small particles called *molecules.* The molecules of all bodies are always in motion. An increase or decrease in the molecular motion of a body causes an increase or decrease in the amount of heat possessed by the body. *Heat is the kinetic energy of molecular motion.*

II. Temperature.—The temperature of a body is the thermal condition which determines the ability of the body to give heat to, or to receive heat from, other bodies. Heat always passes from a body of higher temperature to one of lower temperature until *thermal equilibrium* is established.

III. Quantity of Heat.—Temperature should not be confused with *quantity* of heat. A cup of boiling water taken from a kettle has the same *temperature* as the water in the kettle, but the kettle of water has more *heat* because it contains more water.

IV. Measurement of Heat.—Quantity of heat is measured in *calories.* A calorie is the quantity of heat required to raise the temperature of 1 gram of water 1° C.

V. Effects of Heat.—As a general rule, an increase in temperature causes bodies to expand and a decrease in temperature causes them to contract. This fact is made use of in the construction of thermometers.

VI. The Fixed Points of a Thermometer.—The temperature at which ice melts and that at which water boils are constant quantities and have therefore been chosen by scientists as the two *fixed points* of a thermometer.

A. *The Fahrenheit Scale.*—On the Fahrenheit scale, the melting point of ice is marked 32° and the boiling point of water 212°. The intervening space is divided into 180 equal parts, or *degrees.* These divisions may be extended both above 212° and below 32° as far as desired.

B. *The Centigrade Scale.*—On the centigrade scale, the melting point of ice is marked 0° and the boiling point of water 100°. The intervening space is divided into 100 equal parts, or *degrees.* These divisions may be extended both above and below the fixed points.

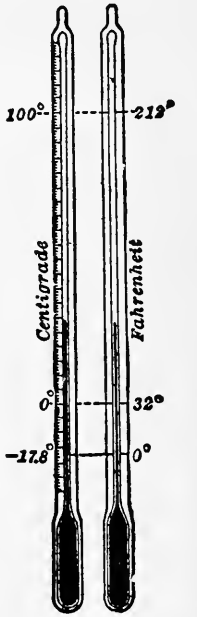


FIG. 20.—CENTIGRADE AND FAHRENHEIT THERMOMETERS

VII. The Mercury Thermometer.—Mercury is an excellent material for use in thermometers because it has a uniform rate of expansion, does not adhere to the glass, and is readily visible. It freezes at — 39° C. and boils at 360° C. Mercury thermometers are used, therefore, in torrid and temperate climates, but not in regions where the temperature drops below — 39° C.

VIII. The Alcohol Thermometer.—Alcohol, colored to make it easily seen, is sometimes used in thermometers. Since the freezing point of alcohol is — 130° C., this type of thermometer is used in very cold climates. It cannot be used in chemical laboratories because alcohol boils at 78.4° C.

IX. The Compound Bar Thermometer.—When a strip of brass and a strip of iron are riveted together, a *compound bar* is formed which warps with a change in temperature. Since the rate at which brass expands is faster than that at which iron expands, the bar warps so that the brass is on

the *outside* of the curve when the bar is *heated* and on the *inside* of the curve when the bar is *cooled* (Fig. 21). This principle is made use of in thermometers for oven doors, for measuring the temperature of flowing lava, and, in general, for measuring temperatures higher than those that can be measured with a mercury thermometer.

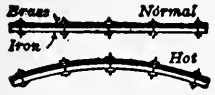


FIG. 21.—EFFECT OF HEATING A COMPOUND BAR

X. Maximum and Minimum Thermometer.—This thermometer registers the highest and the lowest temperature reached in the interval between the reading of the instrument and its previous setting. One type is illustrated in Fig. 22.

A. *Construction*

1. The bulb and tube at the left are filled with alcohol and alcohol vapor.
2. The long bulb in the center and the tube at the right are filled with alcohol.
3. The remainder of the tube is filled with mercury (shown in black).
4. The indicators are capable of being pushed along by the mercury, but are prevented by small steel springs from moving of their own accord.

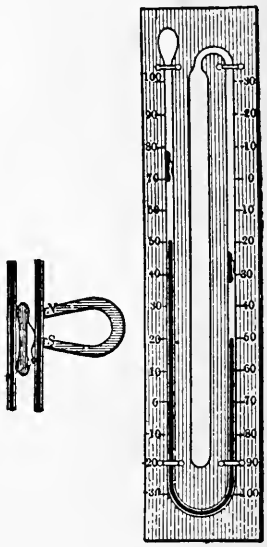


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FIG. 22.—MAXIMUM AND MINIMUM THERMOMETER

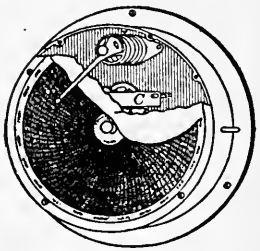
B. *Operation*

1. When the temperature rises, the alcohol in the long bulb in the center expands and pushes the

mercury column upward in the tube on the left. The mercury, in turn, pushes the maximum indicator upward. The minimum indicator remains stationary.

2. When the temperature drops, the alcohol in the long bulb contracts, and the mercury column rises in the tube on the right, pushing the minimum indicator upward. The maximum indicator remains stationary.
3. After reading the thermometer, it is reset by drawing the indicators into position by means of a magnet.

XI. The Clinical Thermometer.—This type of thermometer is used by physicians for determining the blood temperature of persons who are ill. Just below the point indicating the normal temperature of the body (98.6° F.) there is a constriction in the tube. The mercury readily rises past this constriction, but breaks at that point when the temperature begins to drop. A portion of the mercury column thus remains in the tube and indicates the highest temperature reached. The thermometer is reset by shaking.



From PRACTICAL PHYSICS *by Black and Davis, The Macmillan Co.*

FIG. 23.—THE THERMOGRAPH

XII. The Thermograph. — The thermograph (Fig. 23) consists of a compound bar, or coiled compound metal ribbon, connected to a pointer at one end and rigidly fastened at the other end. A pen at the end of the pointer traces a temperature curve on graph paper the divisions of which indicate units of time and temperature. The record thus made is called a *thermogram.* The thermograph is a very important part of the equipment of a Weather Bureau station.

XIII. Transmission of Heat.—Heat is transferred from the place where it is generated to the place where it is usefully applied by one of three ways: *conduction, convection,* or *radiation.*

A. *Conduction.*—When one end of a metal rod is held in a flame, the other end soon becomes too hot to hold. The molecules of the rod in contact with the flame are set into more rapid motion and, in turn, hit the cooler, slower moving molecules near them and set them into more rapid motion. Thus energy is passed along from molecule to molecule by collision. *Conduction is the transfer of heat from a hot body to a cold body, or from one part of a body to another, by molecular collision.*

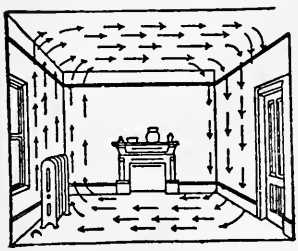


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FIG. 24.—THE HEATING OF A ROOM BY CONVECTION CURRENTS OF AIR

B. *Convection.*—In this method, heat is carried by moving masses of a fluid. Whenever a fluid is heated at the bottom or cooled at the top, *convection currents* are set up. *Convection is the transfer of heat by movements of masses of a fluid.*

Illustration.—When a kettle of water is placed over a gas flame, the layer of water on the bottom of the kettle is warmed by contact, expands, and becomes lighter. It then rises because the cooler and heavier layer of water above it drops and pushes the warmer and lighter water up. Convection currents are thus established and distribute heat to all parts of the water.

Note.—Winds are horizontal portions of convection currents in air.

C. *Radiation.*—In this method, heat is transmitted by means of ether waves. When these ether waves strike a body capable of absorbing heat, they cause the molecules of the body to vibrate more rapidly, thus producing heat. The heat from the Sun, from an open fire, or from a steam radiator is transmitted by this method.

Note.—Heat in the form of ether waves is called *radiant heat.*

XIV. Sources of Heat.—The Sun is the chief source of heat for the surface of the Earth. Other sources are

A. The interior of the Earth.
B. The stars.
C. Friction.
D. Compression.
E. Combustion.
F. Electricity.

XV. Insolation.—The heat energy received from the Sun by radiation is called *insolation.*

XVI. Disposition of Insolation.—Insolation may be transmitted, reflected, or absorbed. Only that part which is absorbed is capable of doing work, such as increasing temperature, manufacturing starch, etc.

A. *Transmission of Insolation*

1. The air absorbs or reflects very little of the Sun's heat energy. It transmits it to the land and water, but is not appreciably warmed by it.

2. Water transmits insolation to a considerable depth. It gradually absorbs this heat and is warmed by it.

B. *Reflection of Insolation*

1. Dark-colored objects are good absorbers and poor reflectors of heat. Light-colored objects are good reflectors and poor absorbers of heat.
2. Water reflects some of the Sun's heat energy and absorbs the rest.
3. Land also partly reflects and partly absorbs this heat energy. The amount reflected depends upon the nature and the color of the material. Seashore sand and bare, light-colored rocks or soil reflect a great deal, while green foliage and dark-colored rocks or soil reflect but little of the Sun's heat energy.

C. *Absorption of Insolation*

1. Water has a very high *specific heat.* This means that, in comparison with land, water is heated very slowly and also cools very slowly. Water is thus a good regulator of temperature.
2. Land is easily heated and also radiates its heat very rapidly. The range of temperature on land is therefore greater than on water. For this reason, land is generally warmer during the day and cooler at night than an adjacent body of water. For the same reason, continents are warmer in summer and cooler in winter than oceans.

XVII. How the Air Is Heated

A. When cool air touches warm land or water, it is warmed by contact.

B. The lower layer of air expands, becomes lighter, and is pushed up by the heavier air nearby or above it.

C. Convection currents are thus established, air currents and winds are set up, and heat is distributed.

Note.—Descending air is heated by compression.

XVIII. How the Air Is Cooled.—The air is cooled by radiation, by contact with cooler objects, and by expansion as it rises.

XIX. Factors Influencing Temperature.—The following factors influence the temperature of the Earth's surface:

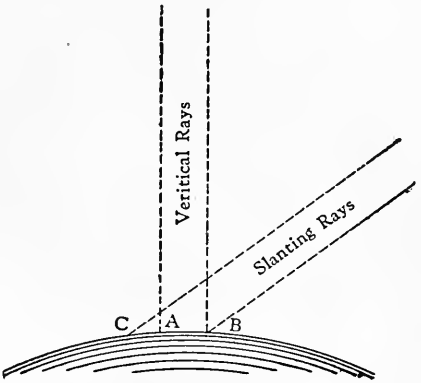


FIG. 25.—VERTICAL AND SLANTING RAYS OF THE SUN

Slanting rays cover a greater area, and their heating effect is therefore less than that of vertical rays.

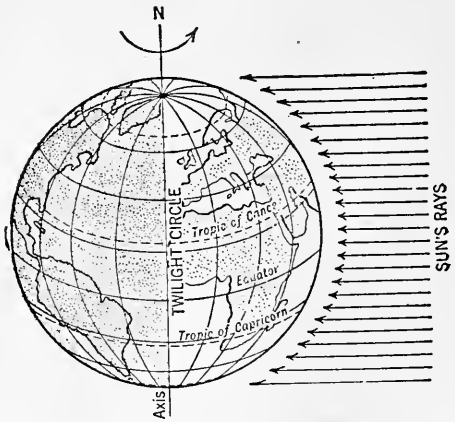
A. *The Angle of Insolation.*—The angle of insolation is the angle at which the direct rays of the Sun strike the Earth's surface (Fig. 25).

1. *The direction of the Sun's rays.* When the rays are vertical, their heating effect is at a maximum because

   (a) The rays are then most concentrated.

   (b) The rays then pass through the shortest distance of air and dust.

2. *The hour of the day.* As the position of the Sun's rays changes from being tangent to the Earth's surface at sunrise, to a vertical position at noon, to being tangent again at sunset, the insolation increases from zero to a maximum and then decreases to zero.



From NEW PHYSIOGRAPHY, *D. C. Heath & Co.*

FIG. 26.—EFFECT OF LATITUDE ON THE ANGLE OF INSOLATION

3. *Latitude.* Latitude affects the angle of insolation because of the curvature of the Earth's surface. In general, as one travels from the equator toward either pole, the angle of insolation decreases, and the insolation therefore becomes weaker (Fig. 26).

4. *Season.* The angle of insolation varies with the seasons. In the northern hemisphere it is more nearly a right angle in summer than in winter.

B. *Altitude.*—The temperature of the air decreases about one degree for every increase of 300 ft. in altitude. At great altitudes the less dense air permits heat to escape more readily by radiation, so that, although insolation is more intense, the temperature is lower.

C. *Nearness to Water.*—Since water has a higher specific heat than land, it warms up more slowly and cools more slowly than land. Large bodies of water, such as lakes and oceans, serve as reservoirs of heat when there is an excess, releasing it when there is a shortage.

1. Land near a body of water is cooler during the day and warmer during the night than land which is far from water.
2. Land near a body of water is cooler in summer and warmer in winter than land at the same latitude which is far from water.
3. The effect of nearness to water on modifying the temperature of the land is greatly increased if the prevailing winds are from the water toward the land.

D. *Direction of Prevailing Winds*

1. In localities where prevailing winds blow from the ocean over land, the range of temperature is less than it otherwise would be.
2. In localities where winds blow from warmer to cooler regions, the temperature of the land is raised. Where winds blow from cooler to warmer regions, the temperature of the land is lowered.

E. *Mountains*

1. Mountains may protect a locality from either warm or cold winds.
2. Slopes facing toward the Sun are, in general, warmer than those facing away from the Sun.
3. Valleys are warmer than elevations.

F. *Ocean Currents*

1. Warm currents raise the average temperature of the land near which they flow, particularly if the prevailing winds are from the water to the land.
2. Cold currents lower the average temperature of the land near which they flow, particularly if the prevailing winds are from the water to the land.

G. *Condition of the Air.*—Clouds and dust in the air check insolation and also the radiation of heat from the Earth.

1. Cloudy days are, in general, cooler than clear days.
2. Cloudy nights are, in general, warmer than clear nights.

H. *Nature of the Land*

1. Dry soil is warmed and cooled more rapidly than moist soil.
2. Dark-colored soil is warmed and cooled more rapidly than light-colored soil.
3. Bare rock or earth is warmed and cooled more rapidly than land covered with green vegetation.

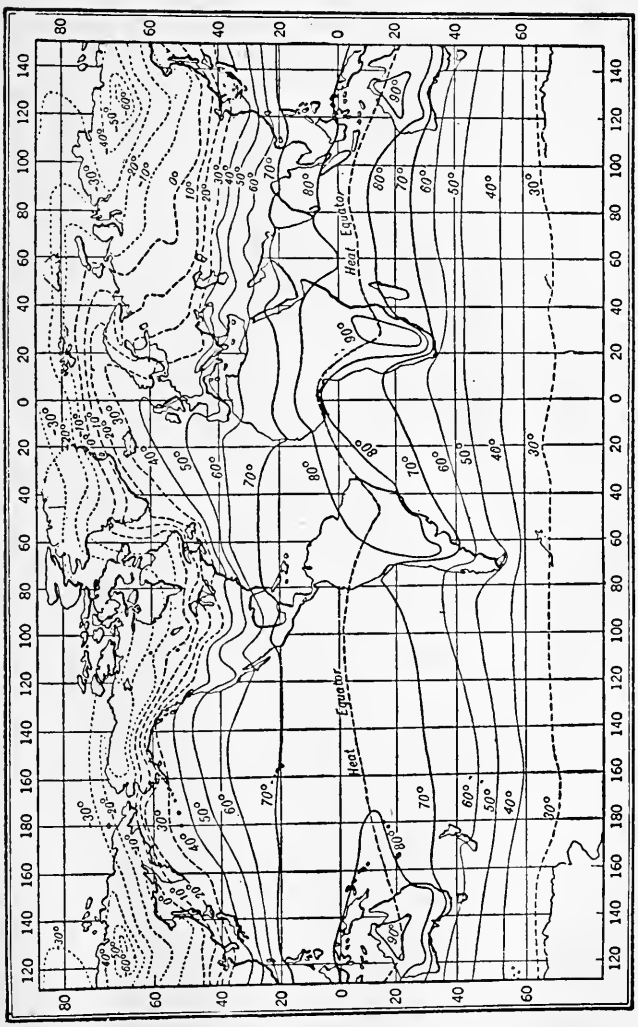


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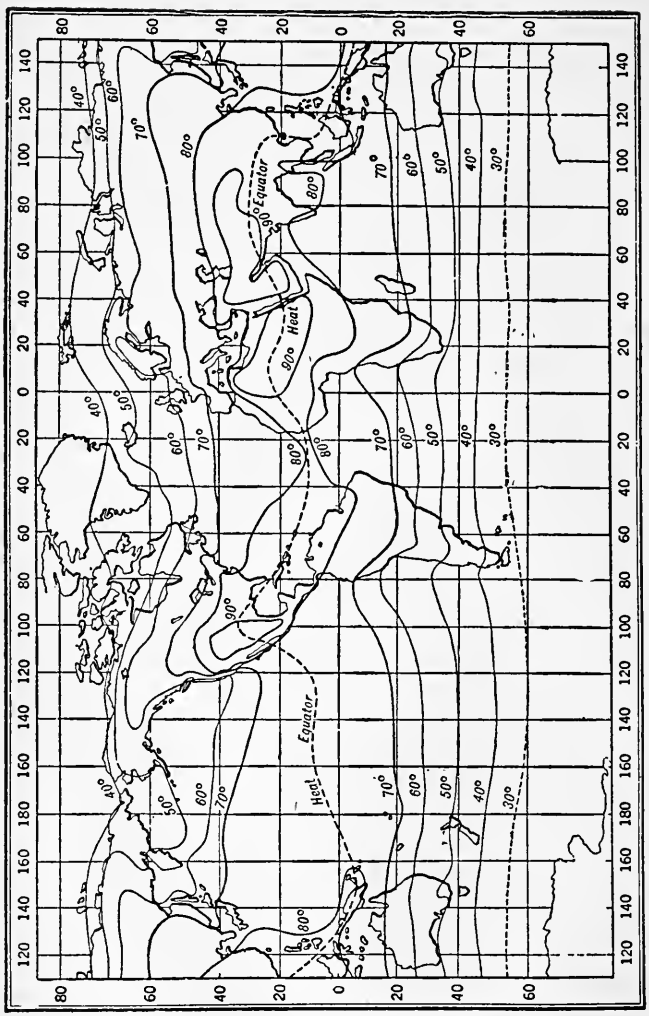
FIG. 27.—TEMPERATURE CHART FOR JANUARY



From New Physiography, *D. C. Heath & Co.*

Fig. 28.—Temperature Chart for July

XX. Temperature Charts.—Lines drawn on a map connecting places having the same temperature are called *isotherms.* Isotherms may represent the temperature at a given hour of the day, as on a United States weather map, or they may represent the average temperature for a period of time, such as a month, a season, or a year (Figs. 27 and 28).

A. *Temperature Gradient.*—If isotherms are close together, they indicate a rapid change of temperature as one travels on a line at right angles to them; if far apart, they indicate nearly uniform temperature conditions over a wide range of country. *Temperature gradient* is the rate (in Fahrenheit degrees) at which the temperature changes in any given direction, measured in a distance of one latitude degree (about 70 miles).

B. *Effect of Latitude.*—In general, isotherms run east and west, since latitude is the chief factor in determining temperature.

1. A loop of an isotherm toward the pole indicates a higher temperature than the average for that latitude.
2. A loop of an isotherm toward the equator indicates a lower temperature than the average for that latitude.

C. *Effect of Altitude.*—Where isotherms cross plateaus or mountains, they loop toward the equator, indicating a lower temperature than the average for that latitude.

D. *Effect of Ocean Currents.*—Where isotherms cross warm ocean currents, they loop toward the pole.

E. *Effects of Land and Water*

1. In summer, because land is then warmer than water, isotherms, in general, loop toward the pole over land as compared with over water.
2. In winter, because land is then cooler than water, isotherms loop toward the equator over land.
3. Isotherms run straighter over water than over land, owing to the effect of the topography of land on temperature.

XXI. The Heat Equator.—The heat equator is the line that indicates the highest temperature on the surface of the Earth. With changes of season the heat equator migrates, in general, from the Tropic of Cancer to the Tropic of Capricorn and back.

A. The range of migration of the heat equator is greater over land than over water.

B. The range of the heat equator is greater in the northern hemisphere than in the southern hemisphere because

1. There is more land in the northern hemisphere.
2. Warm ocean currents are more pronounced in the northern hemisphere than in the southern hemisphere.
3. Summer is seven days longer in the northern hemisphere than in the southern hemisphere.

QUESTIONS

1. Distinguish between, (a) heat and temperature; (b) temperature and quantity of heat.

2. (a) What is the effect of heat on a body? (b) How is the temperature of a body measured? (c) In what units is heat measured?

3. Describe the method of determining the fixed points of a mercury thermometer.

4. What are the freezing and boiling temperatures of water on, (a) the centigrade scale; (b) the Fahrenheit scale?

5. Show under what circumstances, (a) alcohol is a better fluid for a thermometer than mercury; (b) mercury is a better fluid than alcohol.

6. On what scientific principle is each of the following based: (a) a mercury thermometer; (b) a compound-bar thermometer; (c) a thermos bottle; (d) a hot water bottle; (e) a fireless cooker; (f) a hot water heating system?

7. Describe the construction and explain the operation of, (a) a maximum and minimum thermometer; (b) a clinical thermometer; (c) a thermograph.

8. State and explain briefly the method of heat transference that is most effective in each of the following processes: (a) heating a flatiron; (b) heating the Earth by the Sun; (c) heating a room by a hot air furnace; (d) heating a room by means of an open fire.

9. (a) Define *insolation.* (b) What three things may happen to the heat received from the Sun?

10. Compare the methods by which air, land, and water retain and get rid of insolation.

11. (a) What factors influence temperature? (b) Explain why land near a body of water has a smaller variation in temperature than land in the interior of a continent.

12. (a) Define *isotherm.* (b) In summer, do isotherms loop toward the equator or toward the pole, when crossing lowlands; mountains; the gulf stream? In winter?

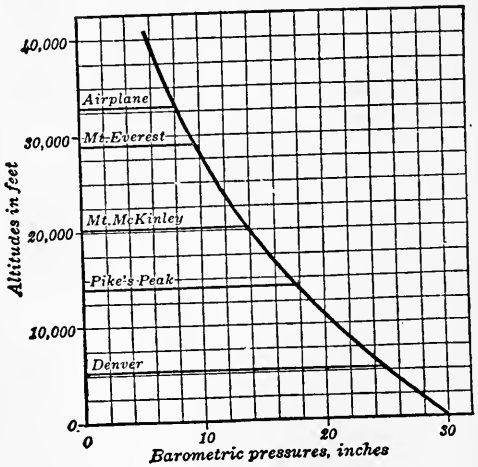
13. Give two reasons why the northern hemisphere receives more heat in summer than in winter.

14. State two reasons why vertical rays of the Sun have a greater heating effect than slanting rays.

CHAPTER X

AIR PRESSURE AND BAROMETERS

I. Air Has Weight.—Careful experiments show that 1 liter of air at 0°C. and 760 mm. pressure weighs 1.293 gms. This is equivalent to 1¼ oz. per cu. ft.



From Practical Physics *by Black and Davis, The Macmillan Co.*

Fig. 29.—Pressure Curve Showing the Relation between Atmospheric Pressure and Altitude

II. Pressure of the Air.—Since air has weight, it exerts pressure. At sea level, the air exerts a pressure of 14.7 lbs. (roughly, 15 lbs.) per sq. in. This pressure is equivalent to about 1 Kg. per sq. cm.

III. Density of the Air.—We have seen that 1 cu. ft. of air at 0°C. and 760 mm. pressure weighs 1¼ oz. We express this fact by saying that the *density* of air is 1¼ oz. per. cu. ft. As one ascends above sea level, the density of the air decreases. Thus, at an altitude of about 18,000 ft. the density of the air is about one-half its value at sea level (Fig. 29).

IV. Boyle's Law.—Most solids and all liquids are almost incompressible. Gases, however, yield readily to pressure. Robert Boyle was the first to show experimentally the relation between changes in pressure and the volume of a gas. Boyle's Law may be stated as follows:

> *The volume of an enclosed mass of gas varies inversely with the pressure exerted on it, the temperature remaining constant.*

Thus, doubling the pressure to which a gas is subjected, reduces its volume to one-half; tripling the pressure, reduces its volume to one-third, etc.

V. Charles' Law.—When a gas is heated it expands and when cooled it contracts. This is true of all gases, including air. Charles' Law expresses the relation between changes in temperature and the volume of a gas. It may be stated as follows:

> *The volume of a given mass of gas, under constant pressure, is directly proportional to its absolute temperature.*
>
> **Note 1.**—Absolute temperature is the centigrade temperature + 273.
>
> **Note 2.**—When the temperature of a gas increases its density decreases.

VI. The Mercurial Barometer.—A barometer is a device for measuring the pressure of the atmosphere. The simple mercurial barometer consists of the following essential parts (Fig. 30):

A. A cup containing mercury.
B. A glass tube, more than 30 in. long and closed at one end.
C. A scale in the back of the tube.

The glass tube is filled with mercury and inverted over the cup. The pressure of the air on the surface of the mercury in the cup just balances a column of mercury about 30 in. long in the tube. The column of mercury in the tube rises or falls with changes in atmospheric pressure.

FIG. 30.—SIMPLE MERCURIAL BAROMETER

VII. The Fortin Barometer.—The Fortin barometer (Fig. 31) is an improvement on the simple mercurial barometer. It has

A. A fixed scale in the back of the tube provided with a vernier for accurate reading.
B. A device for raising or lowering the level of the mercury in the cup to the zero point of the fixed scale. This device consists of a screw with a button on its end, pushing upward against a leather diaphragm at the bottom of the cup of mercury.

FIG. 31.—THE FORTIN BAROMETER

VIII. The Aneroid Barometer.—The aneroid barometer (Fig. 32) contains no liquid, occupies less space, and is therefore much more convenient to carry than a mercurial barometer. It consists of the following essential parts:

A. A hollow cylindrical box from which the air has been partially exhausted. The box is provided with a flexible, corrugated metal cover.

B. A chain and lever connection from the center of the cover to the pointer.

C. A hair-spring to take up the slack in the chain.

D. A dial calibrated by comparison with a mercury barometer.

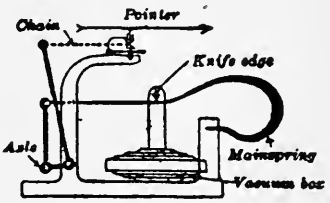
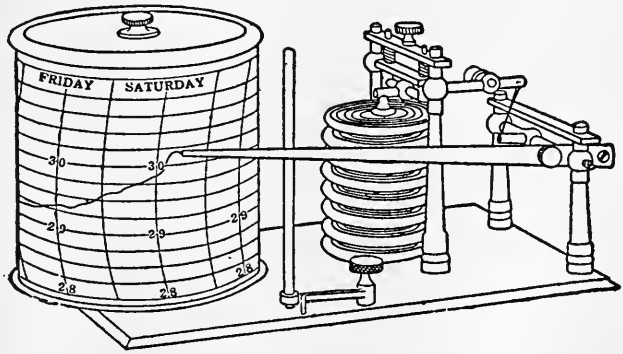


FIG. 32.—THE ANEROID BAROMETER

When the air pressure increases, the flexible cover is pushed inward and communicates its motion to the pointer. When the air pressure decreases, the air inside the box expands and pushes the cover outward.



From PRACTICAL PHYSICS *by Black and Davis, The Macmillan Co.*

FIG. 33.—THE BAROGRAPH

IX. The Barograph.—The barograph is an aneroid barometer arranged like a thermograph (Fig. 23) to draw a curve on graph paper. This curve gives a continuous record of air pressure, in inches of mercury, over a period

of time, usually a week. It is an important part of the equipment of a Weather Bureau station.

X. Uses of the Barometer.—Since changes in atmospheric pressure may be due either to changes in the weather or to changes in elevation above sea level, the barometer is used

A. To foretell the weather.

B. To measure altitude.

XI. The Barometer and Weather Changes

A. *A falling barometer indicates the approach of a low pressure area.* In the United States, the central, southern, and eastern portions of a low pressure area usually have precipitation (rain or snow).

B. *A rising barometer indicates the approach of a high pressure area.* A high pressure area tends to bring cool, clear, dry weather.

C. *An unchanging high barometer indicates clear, settled weather.*

Note.—The relation between air pressure and weather is discussed more fully in Chapter XII.

XII. The Barometer and Changes in Altitude.—As one ascends above sea level, air pressure diminishes and the barometer reading drops. For limited altitudes, the reading drops one-tenth of an inch for every ninety feet of ascent (Fig. 29).

XIII. The Altimeter.—The altimeter is a device usually carried in aeroplanes for measuring altitudes. It consists of an aneroid barometer whose dial is calibrated to show the altitude above sea level in feet.

XIV. Archimedes' Principle.—Archimedes' Principle states that *a body immersed in a fluid is buoyed up by a force equal to the weight of the fluid which it displaces.* Thus a balloon will

A. *Rise* when it weighs *less* than the air which it displaces.

B. *Sink* when it weighs *more* than the air which it displaces.

C. *Float* when its weight is exactly *equal* to the weight of the air which it displaces.

XV. Pressure Charts.—Lines drawn on a map connecting places having the same atmospheric pressure are called *isobars*. Isobars may represent pressure conditions at a given hour of the day, as on a United States weather map, or the average pressure conditions for a period of time, such as a month, a season, or a year.

XVI. Pressure Gradient.—When isobars are close together, they indicate a rapid change of pressure. The *pressure gradient* is the rate at which the pressure changes in any given direction, measured in hundredths of an inch, in a distance of one degree of latitude (about 70 miles).

XVII. Pressure Gradient and Winds.—Winds are caused by a difference in pressure between two places. They always blow from a high to a low pressure area. The larger the pressure gradient, the greater is the velocity of the wind.

QUESTIONS

1. What evidences are there that air has weight?

2. (a) Describe the construction of the simple mercury barometer. (b) Explain how this barometer can be used to measure the pressure of the air.

3. (a) How high would a balloonist have to ascend to leave half of the air beneath him? (b) Would he then be half way to the top of the atmosphere? Explain.

4. Would a cubic foot of air weigh more at sea level or at the top of Mount Washington? Explain.

5. (a) Why does the barometric reading vary at any given place from hour to hour? (b) Explain how a barometer may be used to foretell the weather.

6. Is it necessary that the diameter of the tube be uniform in (a) a barometer; (b) a thermometer? Explain.

7. (a) Why is mercury a better substance than water for use in a barometer? (b) Since mercury is 13.6 times as heavy as water, how long would a water barometer have to be?

8. (a) What advantages has an aneroid barometer over a mercury barometer? (b) What change would you make in an aneroid barometer to adapt it for use as an altimeter?

9. In general, does the barometric reading rise or fall as the temperature rises? Explain.

10. (a) Define *pressure gradient.* (b) What is the relation between the pressure gradient and winds?

CHAPTER XI

WATER VAPOR AND PRECIPITATION

I. Vaporization.—Vaporization is the process of changing a liquid to the gaseous state. It includes evaporation and boiling.

II. Evaporation and Boiling

Evaporation	*Boiling*
Takes place only at the surface of a liquid	Takes place throughout the liquid.
Takes place at any temperature.	Takes place only at the boiling temperature.
Quiet action.	Violent action.

III. Humidity of the Air

A. *Capacity of the Air for Holding Moisture.*—The air has a certain capacity for absorbing and holding moisture. This capacity varies with the temperature, becoming greater when the temperature rises and less when the temperature falls.

B. *Saturation Point.*—When the air contains all the moisture that it can hold at the given temperature it is said to be *saturated.* The saturation point, or *dew point,* is the temperature to which a body of air must be cooled to become saturated.

C. *Absolute Humidity.*—Absolute humidity is the weight of water vapor in a unit volume of air (*e.g.,* 4 grains per cu. ft.).

D. *Relative Humidity.*—Relative humidity is the amount of water vapor which the air holds compared with what it *could* hold at the given temperature if it were saturated.

> **Illustration.**—A relative humidity of 40% means that the air holds 40% of the maximum amount of moisture which it *could* hold at the given temperature. The higher the temperature, the more water vapor the air can hold. If the air is *saturated* with moisture, the humidity is said to be 100%.

IV. The Psychrometer.—The psychrometer is a device for measuring relative and absolute humidity. It consists of two thermometers, one of which is kept wet by means of a wick immersed in a cup of water. The relative or absolute humidity is calculated from the readings of the two thermometers with the aid of a chart or tables.

V. Action of the Psychrometer

A. Evaporation of the water from the wet-bulb thermometer causes this thermometer to read less than the dry-bulb thermometer.

B. If the air is saturated, there is no difference in the reading of the thermometers. The drier the air, the greater is the difference in the readings.

C. By noting the difference in the readings and consulting the tables, the relative or absolute humidity can be determined.

VI. Condensation.—Condensation is the process of changing a gas or vapor to the liquid state. The condensation of water vapor in the air is always caused by the cooling of the air below its saturation point. This cooling of the air may be caused by

A. *Contact with a Cold Surface.*—This results in
   1. The formation of dew, if the dew point is above 32° F.
   2. The formation of frost, if the dew point is below 32° F.

B. *Loss of Heat by Radiation.*—If the cooling of the air takes place near the surface of land or water, it results in
   1. Fog, if the dew point is above 32° F.
   2. Snow clouds, if the dew point is below 32° F.

C. *Mixing of Cold and Warm Currents of Air.*—This results in
   1. Clouds of the fog type, if the dew point is above 32° F.
   2. Snow clouds, if the dew point is below 32° F.

D. *Expansion of Rising Air.*—This also results either in clouds of the fog type or snow clouds, according as the dew point is above or below 32° F.

VII. Precipitation.—The term *precipitation,* as used in physiography, means the formation of dew or frost, or the falling of rain, snow, hail, or sleet.

VIII. Formation of Dew or Frost.—Objects on the surface of the Earth, such as blades of grass or tin roofs, lose heat after sunset by radiation and are thus cooled below the dew point of the adjacent air. The air which touches these cool objects is cooled below its dew point and deposits dew or frost on these objects, according as the dew point is above or below 32° F.

IX. Formation of Rain or Snow.—If, for any of the reasons given above, condensation takes place in sufficient quantity, clouds are formed and result in rain or snow.

X. Formation of Hail and Sleet.—Hail is composed of pellets of ice. The structure of these pellets indicates that they are frozen rain drops, which have become enlarged by successive condensations and freezings upon their surfaces. They are probably formed by rain drops which are carried to high altitudes by strong upward currents of air, as in thunderstorms.

XI. Sheet-Ice.—Sometimes, in winter, rain falls and is immediately frozen, coating trees, grass and other objects with a thin sheet of ice. This is known as *sheet-ice.*

QUESTIONS

1. Compare evaporation with boiling.

2. Describe the cycle of operations that keeps water flowing over Niagara Falls.

3. Describe four ways in which the air may be cooled sufficiently to cause precipitation.

4. (a) Why is water power called *white coal?* (b) Is the source of the stored-up energy in coal and water the same?

5. (a) Describe the formation of rain clouds and snow clouds. (b) In what one respect do these two processes differ?

6. (a) Describe the formation of dew and frost. (b) State the one respect in which these two processes differ.

7. Compare the "sweating" of cold water pipes or of a pitcher of ice water on a warm summer day with the formation of dew on a tin roof.

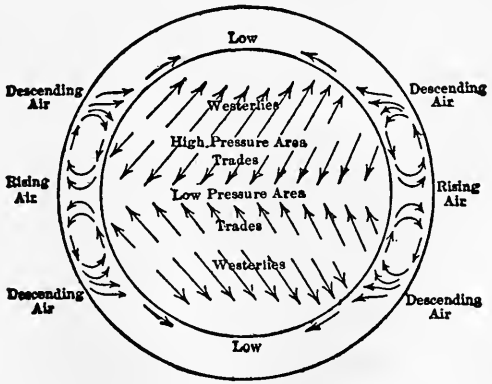
8. (a) Distinguish between relative humidity and absolute humidity. (b) On what scientific principle is the operation of the psychrometer based?

CHAPTER XII

WIND BELTS. CYCLONIC STORMS. RAINFALL

I. Planetary Circulation.—Excessive heat along a belt whose center is the heat equator causes air to expand and rise, thus starting convection currents on a large scale. These currents, together with the rotation of the globular shaped Earth, establish a system of wind belts and belts of calm (Fig. 34).

II. The Wind Belts



From PHYSICS *by Fuller, Brownlee and Baker, Allyn & Bacon.*

FIG. 34.—PLANETARY CIRCULATION OF THE ATMOSPHERE

A. *The Doldrum Belt.*—This is a belt of rising air along the heat equator, caused by excessive heat. It is a belt of calm, and the barometer reading in

it is low. Since the air is rising and being cooled by expansion, there is frequent rain.

B. *The Horse Latitude Belts.*—The descending air of the great convection currents reaches the surface of the Earth at about 25°–35° on either side of the equator. These latitudes are known as the *horse latitudes.* They are belts of calm, and the barometer reading in them is high. Owing to the fact that the air is descending and being warmed by compression, there is little or no rain.

C. *The Trade Wind Belts.*—Winds blow from the high pressure belts of the horse latitudes toward the low pressure belt near the equator, and are known as *trade winds.* These winds tend to blow straight south in the northern hemisphere and straight north in the southern hemisphere. In accordance with Ferrel's Law, however, they are deflected so that they become, respectively, the northeast and southeast trade winds.

III. Ferrel's Law.—Winds are deflected by the rotation of the Earth

A. In the northern hemisphere, to the *right* of the direction which they tend to take.

B. In the southern hemisphere, to the *left* of the direction which they tend to take.

> **Note.**—Ferrel's Law is believed to apply also to river and ocean currents.

IV. Prevailing Westerlies.—Winds blow from the high pressure horse latitudes toward the low pressure areas around the poles. In the northern hemisphere, these winds are the southwesterlies; in the southern hemisphere, the northwesterlies.

V. Mountains and Rainfall.—Where winds have to cross mountains, they are chilled, chiefly by expansion, through being forced into higher altitudes. They therefore shed rain on the windward slopes. When going down on the opposite (*leeward*) slopes, the winds are warmed by compression, have a drying effect, and give rise to desert or semi-desert conditions.

VI. Trade Winds and Rainfall.—Owing to the fact that trade winds blow from cooler to warmer regions, they tend to absorb, rather than lose, moisture. They therefore furnish little rain unless they are forced to climb mountains.

A. Eastward and northeastward slopes of mountains in the trade wind belt of the northern hemisphere have a heavy rainfall and are heavily forested, while the opposite slopes have little rainfall and are either lightly forested or have desert conditions.

> **Examples.**—The eastern slopes of Central America, the West Indies, and the Hawaiian Islands are heavily forested, while the opposite slopes are deserts.

B. Eastward or southeastward slopes of mountains in the trade wind belt of the southern hemisphere have a heavy rainfall and are heavily forested, while the opposite slopes are nearly desert.

> **Examples.**—The Eastern slopes of the Andes Mountains and the east coasts of Brazil and of Australia have heavy rainfall, while the opposite slopes are nearly desert.

C. Some low-lying lands in both trade wind belts are deserts.

> **Examples.**—Portions of Central Australia and Sahara are trade wind deserts.

VII. Prevailing Westerlies and Rainfall.—Prevailing westerlies are, in general, rain-bearing winds, since they blow from warmer to cooler regions.

A. Where prevailing westerlies blow against western coasts and at the same time meet high mountains, they yield a heavy rainfall on the western slopes. The eastern slopes then have desert or nearly desert conditions.

Examples.—The northwest coast of the United States, the west coast of British Columbia, and the west coast of Chile.

B. Lands near the ocean reached by the prevailing westerlies and not having high mountains are well watered.

Examples.—France, England, and Germany.

VIII. Deserts.—By referring to a map, it can be seen that most of the great deserts of the world lie in two belts that include the horse latitudes and the trade winds.

A. Sahara, Arabia, and Central Australia are deserts because they lie in these two belts, and also because mountains prevent rain-bearing winds from reaching them.

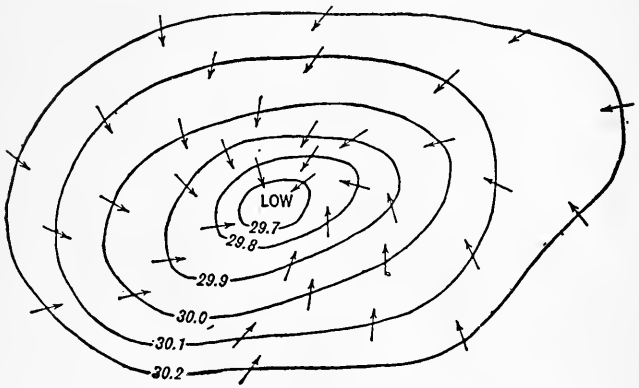
B. The deserts of the Great Basin in Utah, and of Gobi in China, are due to the shielding action of mountains.

IX. Lows.—A low pressure area, or *low,* is caused by excessive heating over a limited area.

A. The air expands, becomes lighter, and is pushed up by the cooler heavier air from round about.

B. Winds tend to blow in from all sides to the center of the *low.* In accordance with Ferrel's Law, and due to the rotation of the Earth, these winds are

deflected toward the right in the northern hemisphere, and toward the left in the southern hemisphere. This results in a whirling motion, the air rising spirally at the center.



From Tarr and Von Englen's NEW PHYSICAL GEOGRAPHY, *The Macmillan Co.*

FIG. 35.—A TYPICAL LOW PRESSURE AREA

X. Cyclonic Storms.—While trade winds blow with remarkable steadiness, prevailing westerlies are broken up by cyclonic and anticyclonic storms. These are great whirlwinds caused by unequal heating. The whirling is caused by the rotation of the Earth.

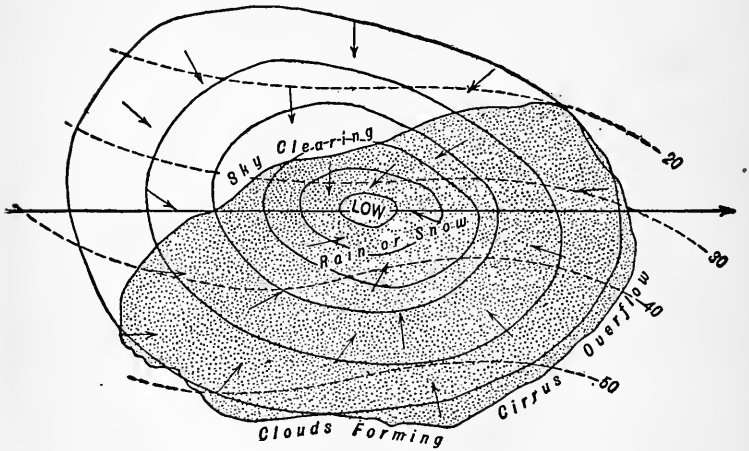
XI. Cyclones.—A cyclone, in the United States, is a large low pressure area having counterclockwise winds, which blow in toward the center and then rise spirally. A cyclone may be very mild or quite violent.

A. *Weather in a Cyclone (in the United States)*

1. The eastern, central, and southern portions of a cyclone area are quite likely to have rain or snow, depending upon the season.
2. The northwestern and western portions have clear, cool, dry weather.

B. *Effects of Cyclones*

1. In general, as the cyclone approaches, the temperature rises, the barometer falls, and clouds form.
2. As the cyclone passes, the temperature remains high, the barometer low, and rain or snow falls.
3. As the cyclone leaves, the temperature drops, the barometer rises, and the clouds dissolve.



From Tarr and Von Englen's New Physical Geography, *The Macmillan Co.*

Fig. 36.—Weather in a Cyclone

C. *Wind Variations in Cyclones*

1. If the center of a cyclone passes north of a given locality, the wind blows first from the east, then veers to southeast, south, southwest, and west.
2. If the center of a cyclone passes south of a given locality, the wind blows first from the northeast, then backs to the north and northwest.

XII. Anticyclones.—In the United States, an anticyclone is a high pressure area, in the center of which air settles down and then blows outward with a clockwise whirl.

A. *Weather in an Anticyclone.*—Anticyclones tend to bring clear, cool, dry weather.

B. *Effects of Anticyclones*

1. As the anticyclone approaches, the temperature drops, the barometer rises, and clouds disappear.
2. As the anticyclone passes, the temperature remains low, the barometer high, and the sky clear.
3. As the anticyclone leaves, the temperature rises, the barometer drops, and clouds form.

C. *Wind Variations in Anticyclones*

1. If the center of the anticyclone passes north of a given locality, the wind blows first from the west, then veers northwest, north, northeast, and east.
2. If the center of the anticyclone passes south of a given locality, the wind blows first from the west, then backs to southwest, south, and southeast.

XIII. Paths of Cyclones and Anticyclones.—Cyclones and anticyclones in the United States generally follow one of three trails.

A. Starting at Puget Sound, they travel southeastward, follow the general direction of the Missouri River, and near its junction with the Mississippi River turn northeast and travel along the Great Lakes and the St. Lawrence River.

B. Starting in the desert regions of the southwest, they travel in a general northeasterly direction up the Ohio River and over New York and New England.

C. Some storms that originate in the West Indies are forced north and northeast over our Atlantic coast states. These are often violent and are sometimes called *hurricanes.*

FIG. 37.—PATHS OF CYCLONIC STORMS

XIV. Tornadoes.—A tornado is a cyclonic storm which differs from a cyclone in having a much smaller diameter, more violent winds, and a funnel-shaped cloud at the center. Tornadoes occur occasionally in the level country in the interior of the United States. They soon blow themselves out, but do a great deal of damage while they last.

XV. Thunderstorms.—These are usually convectional current storms on a small scale, caused by excessive heating. They may also be a portion of the front of a *low.* The rapid upward motion of the air at the center causes the rapid formation of cumulus clouds, which are heavily charged with electricity. These storms are characterized by strong winds, heavy rainfall, and thunder and lightning. Sometimes raindrops are carried upward by the strong rising currents of air, become frozen, and fall as hail.

XVI. Shifting of the Wind Belts.—The heat equator migrates back and forth approximately from the Tropic of Cancer to the Tropic of Capricorn, and forces a shifting of the entire system of wind belts. This accounts for the alternation of rainy and dry seasons in the tropics and in the areas covered alternately by the high pressure belts and the prevailing westerlies.

XVII. Land and Sea Breezes.—These are convectional winds at lakes and seashores, caused by the difference in temperature between land and water.

A. *Sea Breezes.*—During the day the land becomes warmer than the adjacent water. The air over the land becomes heated and rises, and a breeze blows in from the water, thus tending to cool the land.

B. *Land Breezes.*—During the night the land becomes cooler than the water. The convection currents are reversed, and a breeze blows from the land to the water.

XVIII. The Monsoons of India.—The excessive shifting of the heat equator over the Indian Ocean and far into the heated interior of Asia brings an alternation of trade winds to India. In summer the winds blow from the southwest over India, bringing rain. In winter the winds blow from the northeast over India, bringing a dry season.

Note.—Trade winds blow normally from the northeast in the northern hemisphere and from the southeast in the southern hemisphere. However, if either of these winds crosses the equator, the rotation of the Earth, in accordance with Ferrel's Law, changes the wind's direction so that a northeast trade wind becomes a northwest, and a southeast trade wind becomes a southwest. Such a wind is called a *hooked trade,* and is illustrated by the monsoons of India.

QUESTIONS

1. (a) What are *terrestrial winds?* (b) Name the belts of winds and calms that constitute the terrestrial winds.

2. Describe each of the wind and calm belts as to location, direction of movement of air, and precipitation.

3. (a) State Ferrel's Law. (b) Explain how the rotation of the Earth causes the trades and prevailing westerlies to move obliquely.

4. Show how Ferrel's Law accounts for the rotary motion of air in high and low pressure areas.

5. (a) Why do the doldrums, trades, and horse latitudes migrate? (b) Show why this migration produces an alternation of rainy and dry seasons in the tropics.

6. (a) Why do cyclones generally drift northeastward across the United States? (b) In what direction do they drift in Argentina?

7. Describe the three trails that cyclones and anticyclones follow across the United States.

8. Describe the weather conditions in cyclones and anticyclones.

9. Distinguish between *cyclone, hurricane,* and *tornado.*

10. Show the relation between winds and the movement of air in a hot-air heating system.

CHAPTER XIII

WEATHER FORECASTING

I. Weather.—Weather is the condition of the atmosphere at a given place or time, with respect to cloudiness, humidity, winds, pressure, temperature, and electrical condition.

II. Weather Controls.—The most important factors determining weather are:

A. The succession of day and night, due to the Earth's rotation.
B. The succession of the seasons, due to the Earth's revolution.
C. In the temperate zone, the succession of *highs* and *lows,* carried along within the prevailing westerlies.

III. The Weather Bureau.—The Weather Bureau is a branch of the Department of Agriculture of the United States Government. It has charge of

A. Forecasting the weather.
B. The issuing of storm warnings.
C. The display of weather and flood signals for the benefit of agriculture, commerce, and navigation.
D. The gauging and reporting of rivers.
E. The reporting of temperature and rainfall conditions for the cotton, rice, sugar, and other interests.
F. The displaying of frost and cold signals.
G. The distribution of meteorological information in the interest of agriculture and commerce.

IV. Weather Bureau Stations.—More than two hundred Weather Bureau stations are scattered over the United States. These stations are equipped with

A. *Barographs,* for recording atmospheric pressure.
B. *Thermographs,* for recording temperature.
C. *Anaemometers,* for determining the directions and velocities of winds.
D. *Rain gauges,* for measuring the amount of precipitation.

V. Gathering Information.—All stations make regular observations, as nearly as possible at the same instant—8 a. m. and 8 p. m., 75th meridian time. These observations are reported by the stations telegraphically to the central station at Washington and to one another. The most important of these observations are

A. The barometric reading.
B. The temperature.
C. The direction and strength of the wind.
D. The amount and kind of precipitation during the preceding twenty-four hours.
E. The percentage of cloudiness.

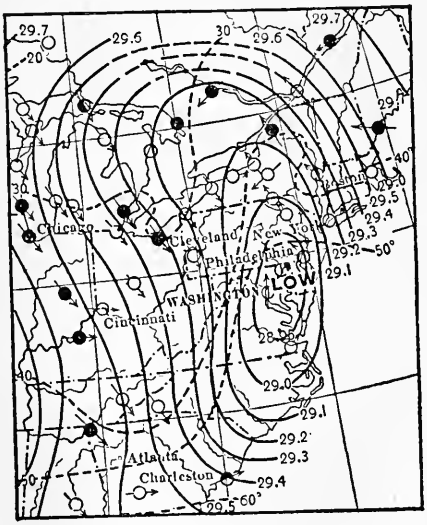
VI. Weather Maps.—The data obtained by the Weather Bureau stations are plotted on a map of the United States, which is then published as the daily weather map. Similarly, one or more sub-stations in every state receive the same information and publish a daily weather map. The following symbols are used on weather maps:

————	= isobars	●	= cloudy weather.
– – – – – –	= isotherms	(r)	= rain (s) = snow
—○→	= direction of wind	*High*	= Center of an anticyclone
○	= clear weather	*Low*	= Center of a cyclone
◑	= partly cloudy weather		

VII. Weather Predictions.—At each station, the weather forecaster, principally from his knowledge of the behavior of *highs* and *lows,* predicts the weather for the following twenty-four or thirty-six hours. The following general principles are used:

A. The *highs* and *lows* follow the trails described on page 83.

B. *Highs* bring clear, cool weather; *lows* bring warm weather and precipitation. See page 82.



From Practical Physics *by Black and Davis, The Macmillan Co.*

Fig. 38.—Portion of a U. S. Weather Map

VIII. Value to the Public.—The publication of weather forecasts is particularly valuable to

A. Farmers, enabling them to prepare against storms and frost.

B. The shipping interests of the coasts and the Great Lakes, who are thus enabled to prepare against storms.

C. Inhabitants of flood plains, who are thus warned against floods.

D. Shippers of perishable goods, who thus prepare against hot or cold waves.

E. Aeroplane pilots in planning distant flights.

QUESTIONS

1. Name four important instruments with which a Weather Bureau station is equipped.

2. Explain how the Weather Bureau, (a) gathers information about the weather; (b) disseminates this information.

3. What three important factors control the weather in the United States?

4. Name five important observations required by the weather forecaster.

5. State five possible instances where weather forecasting is helpful.

CHAPTER XIV

CLIMATE

I. Climate.—Climate is the average condition of the atmosphere with respect to temperature, pressure, winds, and precipitation over a period of time.

II. Climatic Controls.—The following are the principal factors that influence or control climate:

A. *Latitude.*—As one travels from the equator toward the poles, the climate gradually becomes colder, and the contrast between the seasons becomes greater.

B. *Altitude.*—As one travels from sea coast to mountain top, there is the same general change of climate as when traveling from the tropics to the Arctic regions.

C. *Nearness to Large Bodies of Water.*—In localities in the same latitude, there is a greater range of temperature in the interior than at the sea coast. In general, there is more rainfall at the coast than in the interior.

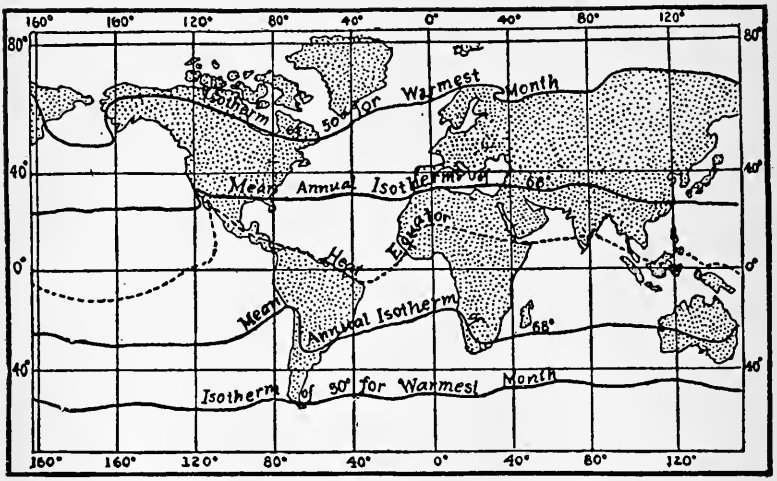
D. *Prevailing Winds.*—Prevailing winds have a very different effect upon leeward and high coasts than upon windward and low coasts (page 80).

E. *Ocean Currents.*—Ocean currents are great distributors of heat from warm to cool regions. They modify the climates of the shores near which they flow, particularly where prevailing winds blow from the water to the land.

F. *Position with Reference to Mountain Ranges.*—In general, there is more rainfall on the windward than on the leeward side of mountains, and, in the

Northern Hemisphere, more sunshine on the southern than on the northern slopes.

G. *Position with Reference to the Paths of Cyclonic Storms.*—The character of the winds and the amount of precipitation received are greatly affected by the passing of cyclonic storms to the north or south of a given locality.



From PHYSIOGRAPHY FOR HIGH SCHOOLS, *Henry Holt & Co.*

FIG. 39.—CLIMATIC ZONES

III. Climatic Zones.—Climatic zones do not coincide exactly with geographic zones.

A. *The Torrid Zone.*—The torrid zone may be considered as the belt included between the two annual isotherms at 68° F. This zone is characterized by a constant high temperature, except where modified by altitude, and by two rainy and two dry seasons a year.

1. The rainy seasons are caused by the migration of the *doldrum belt.* As this belt migrates, it

brings with it calm, or light variable winds, excessive heat, and heavy rainfall. Since this belt crosses the equator twice a year, there occur, annually, two rainy and two dry seasons in all parts, except the margins of the zone.

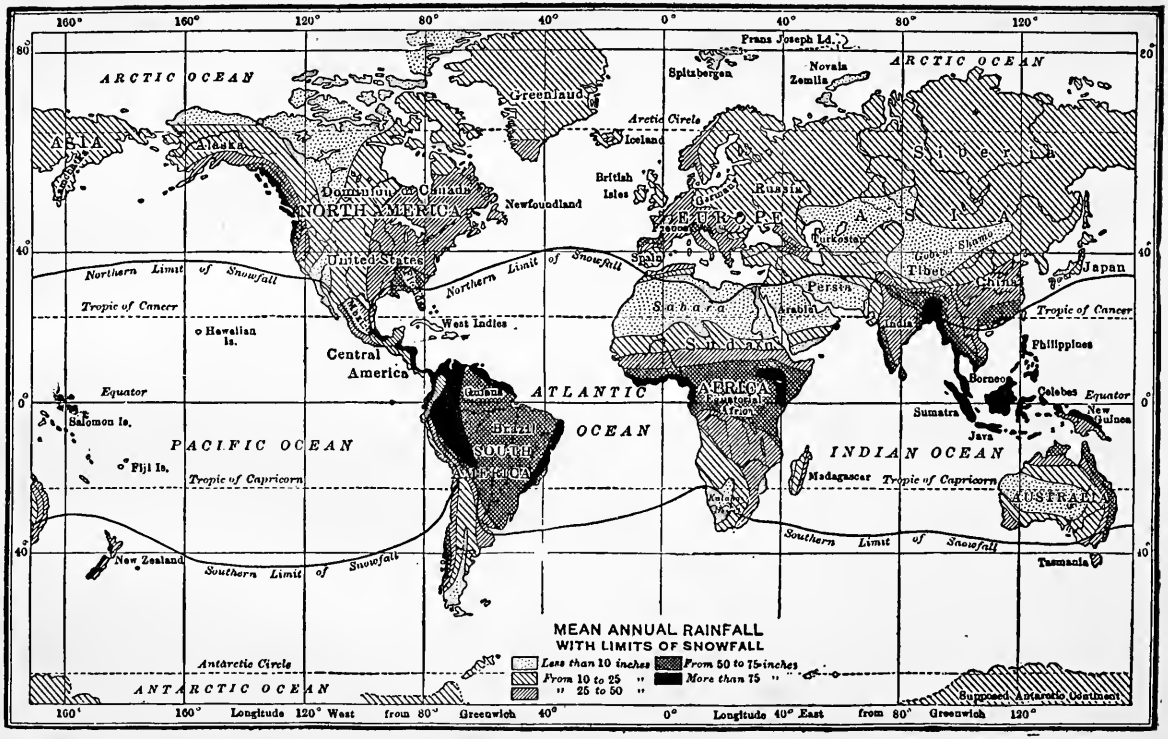
2. Near the Tropics of Cancer and Capricorn (at the margins of the climatic tropic zone), the migration of the wind belts causes one rainy and one dry season a year. In summer, the presence of the trade winds causes a rainy season on elevated lands; in winter, the presence of the horse latitudes causes a dry season.

B. *The Temperate Zones.*—The temperate zones may be considered as extending from the annual isotherms at 68° F. to the summer isotherms at 50° F. The climate of the temperate zones is characterized by

1. Variability of the weather due to cyclonic storms.
2. Wide range of temperature as compared with the torrid zone. This is due to the greater land masses and the greater changes in the angle of insolation as the Earth revolves around the Sun.
3. Four seasons, distinguished by differences in temperature, differences in the length of days and nights, seasons of growth and dormancy of vegetation.

C. *The Frigid Zones.*—The frigid zones extend poleward from the summer isotherms at 50° F. The climate of the frigid zones is characterized by

1. Long, cold winters and short summers.
2. Great range in the length of daylight and darkness.
3. Light precipitation. More snow falls than melts, thus giving rise to glaciers.



From NEW PHYSIOGRAPHY, *D. C. Heath & Co.*

FIG. 40.—RAINFALL CHART

IV. Continental and Marine Climates.—The climate of the interior of continents is in marked contrast to that of sea coasts and of islands in the ocean. In general, there are steadier winds and more rainfall on sea coasts than in the interior.

V. Mountain or Alpine Climates.—The temperature of the air drops about 1° F. for every 300 ft. of ascent. The climate of high altitudes is characterized by moderate precipitation, steady cold winds, and low temperatures. There is also marked contrast between day and night temperatures.

VI. Relation between Wind and Pressure Belts and Rainfall

Wind Belt	Rain	Regions Affected
Doldrums.	Abundant.	Amazon Valley, Central Africa, East Indies.
Trades.	Rainy east coasts.	Venezuela, Colombia, Southeast Mexico, Eastern Central America, West Indies, Southeast Africa, Southeast Australia.
	Dry west coasts.	West coast of Chile and Peru, South Africa, Western Australia.
Transition between Trades and Horse Latitudes.	Rainy and dry seasons.	Northeastern Argentina, Southern Brazil, West Indies, Philippine Islands.
Monsoons.	Rainy and dry seasons.	Southeastern China, India.
Horse Latitudes.	Desert conditions.	Portions of Sahara and Australia.

Wind Belt	Rain	Regions Affected
Westerlies.	The west coasts in low middle latitudes have rainy winters and dry summers.	Southwestern United States, Spain, Portugal, and Morocco.
	The west coasts in middle and high middle latitudes have abundant rain, more in winter than in summer.	Northwestern United States, Western Canada, France, and the British Isles.
	Interiors are dry where shielded by high mountains.	Western interior of the United States, including the Plateau Region, southwestern interior and western plains; northwestern Europe.
	Interiors have sufficient rainfall where not shielded, or where cyclonic storms can bring rain from the southeast and east.	The eastern portion of the Mississippi Valley; northwestern Europe.
	East coasts obtain rainfall from cyclonic storms.	The Atlantic coasts of the United States and Canada.

VII. Climatic Regions of the United States

Region	Subdivisions	Climatic Controls	Rainfall
West Coast.	Low middle latitudes (southwest coast).	Prevailing westerlies. Horse latitudes. High mountains near coast.	10–20 in. Seasonal (winter). Adapted for fruit growing.
	Middle and high middle latitudes (western and northwestern coasts).	Prevailing westerlies. Japan current. High mountains near coast.	30–100 in. Rain every month — slightly more in winter.

Region	Subdivisions	Climatic Controls	Rainfall
Interior Dry.	Plateau (Oregon, Washington).	High altitude. Prevailing westerlies. Leeward side of high mountains. Distance from sea.	10–20 in. Rain every month. Adapted to wheat and fruit growing.
	Southwest interior (Arizona, Nevada, Utah).	High altitude. Prevailing westerlies. Horse latitudes. Leeward side of high mountains. Distance from sea.	3–10 in. Desert. Poor grazing.
	Western plains to 100th meridian (middle of Dakotas and south).	Leeward side of high mountains. Position with respect to cyclonic storms (in the path of the *low*). Distance from sea.	10–20 in. More rain in warm months. More rain toward south. Adapted to grazing.
Interior Humid.	Eastern part of western plains (from western boundary of Iowa and south to the Appalachians).	Distance from sea. Position with respect to cyclonic storms (in the path of the *low*).	30–40 in. More rain in warm months. Adapted to general agriculture.
East Coast.	Maine to Florida.	Nearness to sea. Position with respect to cyclonic storms (eastern and southeastern portion of *low* and Atlantic Ocean hurricanes).	40–80 in. Adapted to general agriculture.

VIII. The Pacific Coast Region.—This region extends inland from the Pacific Ocean for a distance of about two

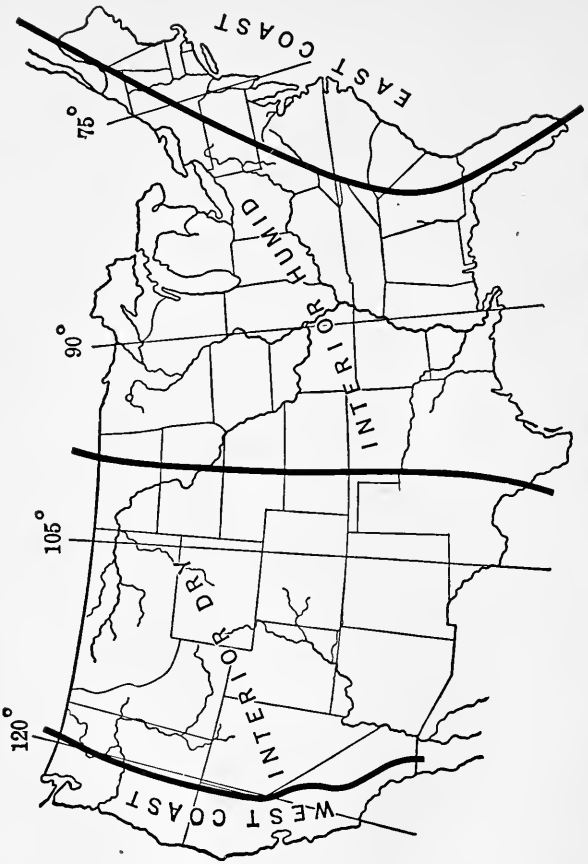


Fig. 41.—Climatic Regions of the United States

hundred miles to the Sierra Nevadas and the Cascade Range. It is characterized by an equable climate, in contrast with the variable climate of the east coast. There is a gradual increase in the annual rainfall and a decrease in the average temperature from south to north. This region has two subdivisions.

A. *The Southwest Coast (Low Middle Latitudes).*—The climate of this region is influenced by the prevailing westerlies and the horse latitudes.

1. In summer, the westerlies blow over land warmer than themselves and therefore do not shed rain until they climb the high mountains. In winter, since the land is then cooler than the air, they shed a moderate amount of rain. This causes a rainy and a dry season, with an annual rainfall of from 10–20 in.
2. The climate of this region is characterized by warm temperatures, clear skies, and sunshine.

B. *The West and Northwest Coasts (Middle and High Middle Latitudes).*—The westerlies blowing over the Japan current give this region a very mild, equable climate with abundant rainfall. Owing to the fact that the land is cooler in winter, more rain falls in winter than in summer.

IX. The Plateau Region.—This region includes the high plateau lands lying between the Rockies and the Cascade Range in eastern Washington and Oregon. The climate of this region is characterized by dryness, clear skies, and a great range of temperatures between summer and winter. Its principal climatic controls are its latitude, altitude, and position east of high mountains. Its altitude is largely responsible for what little rainfall it has, which makes possible the growing of wheat in this region.

X. The Southwest Interior.—This region includes the Great Basin and the Arizona Plateau. It is the driest portion of the United States and has a wide range of temperature. Its dryness is due in part to its position east of high mountains, and in part to the horse latitudes. Although

there is some grass for grazing, it is a very poor grazing country.

XI. The Western Plains to the 100th Meridian.—This is a long narrow belt east of the Rocky Mountains. Its principal climatic controls are its position east of high mountains, its position in the extreme western portion of low pressure areas, and its distance from the sea. It has, therefore, little rainfall and a great range of temperature. There is sufficient rainfall for the growth of grass, and it is therefore a great natural grazing field.

XII. The Eastern Part of Western Plains.—This is a long, narrow belt, just west of the Mississippi Valley, far enough east in the low pressure areas to receive from 20–30 in. of rainfall. This amount of rainfall is sufficient for agricultural purposes, especially for grain growing. Its great distance from the sea gives it a wide range of temperature.

XIII. The Western Slope of the Appalachians to the Western Boundary of Iowa and South.—The climate of this region is very variable and is dominated by a succession of high and low pressure areas moving within the prevailing westerlies.

A. The rainfall in this region is due to moisture carried inland by cyclonic winds from the Atlantic Ocean and the Gulf of Mexico. The Appalachians are not high enough to affect greatly the rainfall of the land which they shield.

B. There is abundant rainfall in this region for agriculture and forest growth. In general, there is more rain in the south than in the north.

XIV. The East Coast.—Along the east coast the climate is less variable than in the interior, but more variable than on the west coast.

A. Its position with respect to cyclonic storms gives it abundant rainfall for general agriculture and for forest growth.

B. There is more rain in the south than in the north, and more rain in winter than in summer.

C. Hurricanes originating in the West Indies sometimes travel up along the coast and do considerable damage because of the violence of their winds.

QUESTIONS

1. Distinguish between, (a) *light zones* and *climatic zones;* (b) *weather* and *climate.*

2. (a) Name seven important climatic controls. (b) Give an illustration of the effect of each.

3. Compare, (a) interior climates with sea-coast climates; (b) torrid climates with temperate climates.

4. Compare east coast climates with west coast climates, (a) in the temperate zones; (b) in the torrid zone.

5. Describe the characteristics and the principal climatic controls of the climate of, (a) the Pacific coast of the United States above San Francisco; (b) below San Francisco; (c) the Arizona Plateau; (d) the Prairies; (e) the Atlantic coast.

6. Explain why there is a gradual decrease in rainfall from, (a) the Atlantic coast to the Rockies; (b) Florida to Maine.

7. Explain why England has a much milder climate than Labrador.

8. Explain why Portland, Maine, has a much more variable climate than Portland, Oregon.

9. Explain why St. Louis has a greater range of temperature than Baltimore, and Baltimore a greater range than Los Angeles.

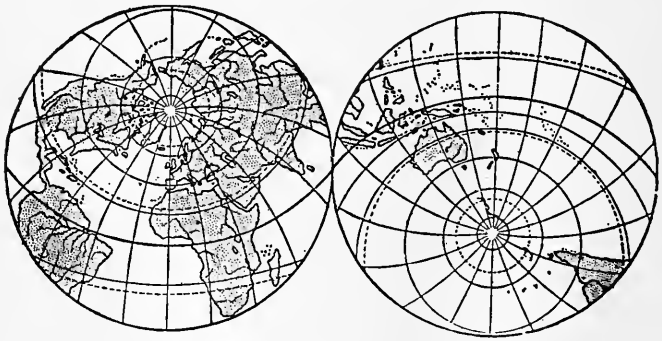
10. In the case of some of the West Indies Islands, why is there a deficiency of rainfall on one side of the island and an abundance of rainfall on the other side?

CHAPTER XV

THE OCEANS

I. The Oceans.—The oceans occupy approximately three-quarters of the Earth's surface, mostly in the southern hemisphere. Although all the oceans really form one great ocean, there are five large divisions:

A. Atlantic Ocean
B. Pacific Ocean
C. Indian Ocean
D. Arctic Ocean
E. Antarctic Ocean



From Physiography for High Schools, *Henry Holt & Co.*

Fig. 42.—Relative Amounts of Land in the Hemispheres

There is more land in the northern than in the southern hemisphere, and more land in the eastern than in the western hemisphere.

II. Composition of Sea Water.—Sea water contains, in solution, gases and solids which can be recovered by evaporation. Common salt constitutes about three-fourths of the

dissolved material. The remainder is made up of small quantities of almost every known element, the greater part consisting of sodium, magnesium, and calcium.

III. Density of Sea Water.—The density of sea water is about 1.03 gms. per cc.; *i.e.*, sea water is about 1.03 times as dense as fresh water. Sea water therefore exerts a greater buoyant force on bodies immersed in it. It is easier to swim in salt water than in fresh water. Ships can be more heavily loaded when they sail in sea water than when they sail in fresh water.

IV. Depth of the Ocean.—The average depth of the ocean is about 2½ miles. The greatest depth is about six miles. The Challenger Deep near the Island of Guam (31,600 ft.) and the Aldrich Deep near New Zealand (30,930 ft.) are two famous deep places.

V. Reasons for Saltiness.—Ground water dissolves mineral matter from the soil, and rivers bring this mineral matter into the oceans. Evaporation of water leaves this mineral matter behind, the vapor going back over the land to bring another load. Since this process has been going on for a very long time, enough mineral matter has accumulated in the oceans to make the water salty.

VI. Temperature of the Ocean.—The temperature of the surface water varies from about 30° F. near the poles to about 80° F. near the equator. These temperatures vary somewhat with the change of seasons. The temperature gradually decreases with the depth. At a depth of about half a mile, the temperature is about 40° F.; at the bottom it is about 35° F.

VII. The Ocean Floor.—There are mountains and valleys, plains and plateaus on the bottom of the ocean. The slopes are much less steep than is usual on land owing to the fact that material is constantly settling to the bottom. Minor irregularities are absent because there are no streams of running water to carve ravines.

VIII. Deposits on the Ocean Floor

A. Beyond the mud deposits of the continental shelf and in comparatively deep water, the deposits consist chiefly of the shells of microscopic animals that live in the warm surface water. When these animals die, their shells sink to the bottom. Accumulations of these deposits form a deep layer of soft gray material, called *ooze*.

B. In the deepest parts of the ocean the gray ooze is replaced by red clay. This is believed to occur because the small sea shells dissolve in water where the pressure is very great, leaving volcanic and meteoric dust to settle. The presence of iron in this material gives the clay a red color.

IX. The Continental Shelf.—Material washed down from the land by running water and deposited in the ocean off shore has gradually produced an extension of the continental mass into the ocean, forming what is called the *continental shelf*. This material was spread out by waves and currents and formed a gently sloping smooth floor, extending seaward from ten to a hundred miles. There is then a sudden descent into deep water.

X. Deposits on the Continental Shelf.—Since heavy particles washed down into the ocean settle first, and lighter particles later, we find deposits of gravel near mouths of rivers and on rocky coasts, and deposits of sand beds elsewhere along the shore. Mud beds are found beyond the sand beds and also in quiet bays.

XI. Economic Importance of Oceans. — The oceans serve as

A. Highways of trade and travel.

B. Storehouses of food.

C. Sources of moisture for rain-making.

D. Regulators of temperature.

QUESTIONS

1. (a) What are the relative amounts of land and water on the surface of the Earth? (b) Where is the greater part of this land concentrated?

2. (a) Were the oceans ever fresh? (b) Why are the oceans salty?

3. Compare the relief features of the ocean floor with those of dry land.

4. (a) How was the continental shelf formed? (b) Describe the deposits on the continental shelf.

5. (a) Describe the deposits on the ocean floor. (b) Why are some of these deposits gray and others red?

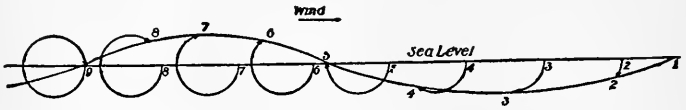
6. Describe four ways in which the oceans are of economic importance.

CHAPTER XVI

MOVEMENT OF OCEAN WATER

I. Types of Motion.—Ocean water has three principal types of motion: *waves, currents* and *tides.*

II. Wave Motion.—Attach one end of a rope to a hook in the wall. Give the other end a snap with the hand. You will see a disturbance (*wave*) travel along the rope, hit the wall, and be reflected back. It is obvious that the material of the rope does not move forward; it is merely the disturbance that passes along the rope. In the case of water waves, each particle of water moves up and down in an elliptical path in such a way as to create a wave form which alone travels forward.



From New Physiography, *D. C. Heath & Co.*

Fig. 43.—Movement of Particles of Water in a Water Wave

III. Causes of Water Waves.—Most water waves are caused by friction between wind and water. Other causes are moving boats, volcanic eruptions, and earthquakes occurring under water.

IV. Effects of Water Waves

A. They carry bubbles of air down under the surface of the water, thus aërating the water.

B. They modify shore lines, building reefs or eating into cliffs.

1. Material deposited on the shore within the zone of wave action forms a *beach.*

2. When material carried out by undertow meets material brought in by waves, it is deposited in the form of a *bar.*
3. When a bar is built up above the surface of the water it is called a *reef.*
4. The extension of a beach or reef due to the combined action of waves and shore currents is called a *spit.*

> **Examples.**—The chalk cliffs of England were caused by wave action. The long narrow islands on the south shore of Long Island are reefs. Sandy Hook, at the entrance of New York Harbor, and Cape Cod, are spits.

C. They destroy harbor structures and shipping.

V. Currents.—Currents are caused by the horizontal motion of ocean water.

A. *Causes of Currents*

1. Currents are principally caused by the steady winds of the planetary circulation, the trades, and the prevailing westerlies.
2. Contributory causes are differences in temperature, differences in the rate of evaporation, and the pouring of water into the oceans by rivers.

B. *Names of Currents*

1. In the North Atlantic, the *North Equatorial Current* flows westward from Africa to the West Indies. It turns north, and then, as the *Gulf Stream,* turns northeast from Florida to near western Europe where it branches, forming the *North Atlantic Drift* and the *West Wind Drift.* The latter turns south as the *Canaries Current,* thus completing the circuit.

2. In the South Atlantic, the *South Equatorial Current* flows westward from Africa to Brazil. It turns south as the *Brazil Current,* east as the *West Wind Drift,* and north as the *Benguela Current.*
3. In the North Pacific, the *North Equatorial Current* flows westward from Mexico to the Philippines. It turns north as the *Japan Current,* or *Kuro Siwo,* east as the *West Wind Drift,* and south as the *California Current.*
4. In the South Pacific, the *South Equatorial Current* flows westward. It turns south as the *Australian Current,* east as the *West Wind Drift,* and north as the *Peruvian Current.*
5. In both oceans there is an *Equatorial Counter Current* between the two great circulations. These counter currents flow from west to east.
6. South of the continents there is a complete circulation of the *West Wind Drift* around the world from west to east.

VI. The Sargasso Seas.—The great ocean currents circulate clockwise in the northern hemisphere and counterclockwise in the southern hemisphere, enclosing great eddies of quiet water, sometimes called *Sargasso Seas.* Over these seas the winds are usually light and variable, or calm. Floating objects, such as seaweed (*sargassum*) and derelict ships tend to accumulate in them. This is particularly true of the *North Atlantic Eddy* east of Florida, which is known as the *Sargasso Sea.*

VII. Effects of Ocean Currents.—Ocean currents serve to distribute heat from the Torrid Zone to the Temperate and Arctic regions, and especially to those shores where prevailing winds blow from the water to the land over warm currents.

Examples.—England and Norway have very mild winters as compared with the lands in the same latitudes across the Atlantic (Labrador and Greenland) because prevailing westerlies carry heat to them from the Gulf Stream. Similarly, the strip of coast west of the Rockies in Alaska and British Columbia has a much milder climate than is usual in those latitudes, because of the Japan Current and the prevailing westerlies.

VIII. Tides.—Tides are the periodic rise and fall of the ocean water, caused by the gravitative pull of the Moon and the Sun. The tide is said to *flow* while it is rising and to *ebb* while it is falling. There are two sets of tides: *lunar* and *solar*. The larger *lunar tides* dominate; the *solar tides* serve merely to modify the range of the lunar tides.

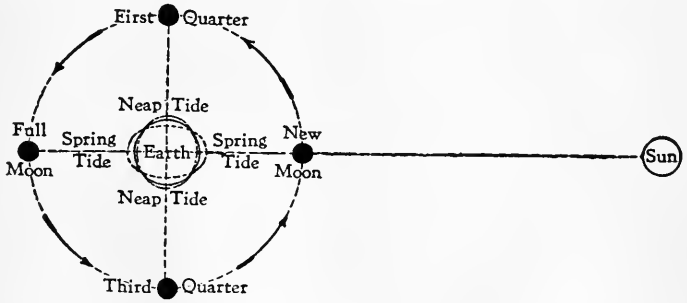


FIG. 44.—RELATIVE POSITIONS OF THE SUN, MOON, AND EARTH AT NEAP TIDE AND SPRING TIDE

IX. Cause of Tides.—The mutual attraction between the Earth and the Moon pulls the ocean water up toward the Moon. On the side of the Earth opposite to the Moon, centrifugal force throws the water outward from the Earth. As the Earth rotates, these two crests, with troughs between them, are drawn around the Earth from east to west, thus causing the tides.

Note.—These crests and troughs are modified by the tides which the Sun tends to cause.

X. Kinds of Tides

A. *Spring Tides.*—At new and full moon, lunar and solar tides combine to form a tide of great range, called a *spring tide.*

B. *Neap Tides.*—At first and third quarters, lunar and solar tides oppose each other and form a tide of small range, called *neap tide.* The crest of the solar tide is then in the trough of the lunar tide.

XI. Range of Tides.—In the open ocean, tides rise about two feet. In *V*-shaped bays they may rise higher. There are many indentations along the coast of Maine where the tide rises as high as 20 ft. In the Bay of Fundy, the range is from 50–60 ft.

> **Note.**—Ships can enter and leave a harbor having a large tidal range, such as that at Liverpool, only at high tide. This is an economic disadvantage, entailing loss of time and the construction of expensive harbor structures.

XII. Time Interval of Tides.—The time that elapses from one high tide to the next is 12 hours and 26 minutes. The tide rises, therefore, 52 minutes later each day.

XIII. Tidal Races.—Strong currents of water are caused by differences in the level of the water in connected bays

A. When tides rise higher in one bay than in the other.

B. When there is a time interval between the respective tides in the two bays.

> **Illustration.**—High tide rises higher in Long Island Sound than in New York Bay, thus causing a strong current of water from the Sound to the Bay. Later the ebb tide in the Sound is lower than the level of the water in the Bay, and the current is therefore reversed in the narrow strait between Long Island and Manhattan.

QUESTIONS

1. What are the three principal motions of ocean water?

2. What is meant by *beach; bar; spit?*

3. (a) State three important effects of waves. (b) Give an example of each.

4. What is the cause of, (a) ocean currents; (b) waves; (c) tides?

5. Name the ocean currents in, (a) the North Atlantic; (b) the South Atlantic, (c) the North Pacific; (d) the South Pacific.

6. Compare ocean currents with the movement of water in a hot-water heating system as to, (a) cause; (b) effect.

7. What are the relative positions of the Sun, Earth, and Moon at (a) spring tide; (b) neap tide?

8. What is the average time interval between two successive high tides?

9. (a) What is meant by *tidal range?* (b) Why are spring tides higher than neap tides?

10. Discuss the economic importance of, (a) waves; (b) ocean currents; (c) tides.

CHAPTER XVII

MINERALS AND ROCKS

I. Minerals.—A mineral is an inorganic substance occuring naturally in the Earth's crust. It has a definite chemical composition and definite physical properties.

II. Common Minerals

Name	Description and Properties
Quartz.	Very hard substance. Crystals are hexagonal prisms, with hexagonal pyramids at one or both ends. Breaks with a conchoidal fracture. When pure, it is transparent and colorless. *Rose quartz, amethyst, opal* and *onyx* are slightly impure or closely related forms.
Feldspar.	Softer than quartz. Cleaves readily in two directions, leaving smooth, flat, shining surfaces. Easily worn away by erosion, forming clay. Pure, white clay (*kaolin*) is derived from feldspar. It is used in making the best porcelain and china.
Mica.	Very soft substance. Cleaves into exceedingly thin, flexible sheets. It is used for stove windows and as an insulator in electric work. Like feldspar, mica is chemically complex, easily eroded to make clay, and furnishes many of the elements needed to make soil fertile.

Name	Description and Properties
Calcite.	A transparent, colorless crystal, when pure. Cleaves readily in three directions not at right angles to each other. Objects viewed through it appear double. Forms the basis of limestone and marble. Easily scratched with a knife. Dissolves readily in water containing carbon dioxide in solution.
Talc.	Soft, light-colored material. When ground, it is used as talcum powder.
Gypsum.	Soft, light-colored material, occurring in several forms. As *alabaster,* it is used for making ornaments. Its most important use is in the manufacture of plaster of Paris.
Hornblende.	Hard, black substance. Cleaves readily in two directions. Decays on exposure to moist air, showing brown and red stains due to the presence of iron.
Magnetite.	Hard, black, heavy oxide of iron. Forms a valuable iron ore. Shows magnetic properties.
Iron Pyrites.	Heavy, yellow sulphide of iron. Occurs in the form of cubical crystals. It is sometimes mistaken for gold, and is therefore called "fool's gold."

Note.—Chemically, *quartz* is silicon dioxide, or silica; *calcite* is a form of calcium carbonate; *talc* is a form of magnesium silicate; *gypsum* is hydrated calcium sulphate.

III. Coal Formation

A. Coal was formed by the slow, partial decomposition of vegetable matter out of contact with the air and subjected to high temperature and great pressure.

B. Anthracite or hard coal is the result of the greatest decomposition, and of great heat and pressure. Most of its volatile matter has been driven off. It is the nearest to pure carbon among the different kinds of coal.

IV. The Coal Series

Name	Description
Peat.	First step in the formation of coal. Consists of partly decayed and spongy vegetable matter, found in swamps. Brown in color. When dried, it can be used as a fuel.
Lignite.	Imperfectly formed brown coal, occurring in enormous quantities in all parts of the world.
Bituminous Coal.	Black, soft coal. Found in large quantities in Pennsylvania, West Virginia, Illinois and many other places. Used as a fuel in factories.
Anthracite Coal.	Black, hard, and shiny solid, found in eastern Pennsylvania. Used as a fuel, mostly for domestic purposes.

V. Petroleum.—Petroleum, or mineral oil, is the source of gasoline, kerosene, and lubricating oils. It is found in Pennsylvania, Texas, California, and in many other places.

VI. Natural Gas.—Great deposits of natural gas are found in Pennsylvania, Texas, California, and in many other places.

VII. Rocks.—A rock is a mass composed of one or more kinds of minerals.

A. *Bed Rock.*—Bed rock is rock attached to the main mass of the solid crust of the Earth.

B. *Mantle Rock.*—Mantle rock consists of large and small fragments of rock resting on top of the bed rock.

VIII. Classes of Rocks.—Rocks are commonly divided into three classes, according to origin.

A. *Igneous Rock.*—Igneous rock is rock that was formed by cooling from the molten state.

1. *Granite.*—There are many varieties of granite, but all contain the minerals quartz, feldspar, and either mica or hornblende. Granite contains visible crystals and is used for building and for making monuments.
2. *Trap.*—A dense, dark rock, related to granite. It has minute crystals because it cooled rapidly. It is used for foundations and road building.
3. *Pumice.*—A light-gray, porous, glassy rock, related to granite. It is of volcanic origin. Used for scouring.
4. *Obsidian.*—A dense, dark, glassy rock, related to granite. It is of volcanic origin, and has a conchoidal fracture. Used by Indians for cutting and for making arrow-heads.

B. *Sedimentary Rock.*—Sedimentary rock was formed from material that settled to the bottom of a body of water. This rock is quite likely to contain fossils of animal and vegetable life.

1. *Clay.*—Clay consists of very finely divided material, not consolidated to form solid rock, which settled to the bottom of quiet water. It is used in making brick, terra cotta, and pottery.

2. *Shale.*—Shale is consolidated clay. It is impervious to water, and often contains fossils. Used in the manufacture of cement.
3. *Sandstone.*—Sandstone consists of particles of sand cemented together by a natural cement. It was formed from sand which settled in gently moving water. It is used for building purposes and as an abrasive.
4. *Conglomerate.*—Conglomerate is consolidated gravel, usually containing some shale. It was formed from material which settled in rather rapidly moving water.
5. *Limestone.*—Limestone consists of consolidated sea shells, usually microscopic in size. It is largely composed of calcium carbonate and is therefore readily acted upon by weak acids. It is used for building purposes and in the manufacture of cement.

C. *Metamorphic Rock.*—Metamorphic rock was formed from either igneous or sedimentary rock by the action of heat, pressure, or water, or by a combination of these.

1. *Slate.*—Slate is metamorphosed shale. It is harder and more durable than shale. It cleaves into thin sheets, and is used for roofs, blackboards, and electric fixtures.
2. *Gneiss.*—Like granite, gneiss is composed of crystals of quartz, feldspar, and mica. Unlike quartz, it has these minerals arranged in layers. It may be either metamorphosed granite or a primary rock.
3. *Quartzite.*—Quartzite is metamorphosed sandstone. It consists of grains of sand cemented together by silica.

4. *Marble.*—Marble is metamorphosed limestone. It is used for building purposes, and for making monuments and statuary.

> **Note.**—Metamorphosed rock is usually found in mountainous regions because the necessary heat and pressure are present during mountain formation.

IX. Some Artificial Mixtures

A. *Wall Plaster.*—Wall plaster is a weak, artificial rock, usually made of a mixture of lime and sand.

1. Lime is made by strongly heating limestone. The heat drives off carbon dioxide, leaving calcium oxide, or lime.
2. Hardening of the plaster takes place slowly over a period of a year or more as carbon dioxide is taken up again by the lime. Crystals of limestone are formed during the process of hardening. These crystals interlock around the grains of sand, thus binding the entire mass together.

B. *Concrete.*—Concrete is a strong artificial rock made of a mixture of cement and sand or gravel.

1. Cement is made by strongly heating a mixture of limestone and shale. The heat drives off the water of crystallization.
2. Hardening takes place when the cement absorbs water of crystallization, forming crystals which bind the entire mass together.

C. *Plaster of Paris.*—Plaster of Paris is made by strongly heating gypsum, thus driving off the water of crystallization. When the powder is moistened, hardening takes place because water of crystallization is then again absorbed and crystals are formed.

QUESTIONS

1. Distinguish between, (a) *rock* and *mineral;* (b) *bed rock* and *mantle rock.*

2. (a) Classify each of the following substances as to whether it is a rock or a mineral, and, as to origin, whether it is igneous, metamorphic, or sedimentary: graphite, mica, limestone, slate, magnetite, sandstone, quartzite, feldspar, pumice, calcite, anthracite, obsidian, gypsum, marble, sulphur, chili saltpeter, trap. (b) State a use for each substance.

3. (a) How is lime formed from limestone? (b) What causes wall plaster to harden?

4. (a) How, and from what, is plaster of Paris made? (b) What causes plaster of Paris to harden?

5. Discuss the four principal stages in the development of coal.

6. (a) Distinguish between *concrete* and *cement.* (b) What causes concrete to harden?

7. (a) Discuss the economic importance of coal and oil. (b) Show that each has its own particular field of usefulness.

8. What natural resources in the United States are, (a) practically unlimited in extent; (b) in danger of being used up?

CHAPTER XVIII

MANTLE ROCK

I. Mantle Rock.—Mantle rock consists of large and small fragments of rock material overlying the bed rock. It was formed from bed rock by weathering.

II. Kinds of Mantle Rock

A. *Residual Mantle Rock.*—Residual mantle rock consists of fragments which remained where they were first formed.

B. *Transported Mantle Rock*

1. *Alluvial.*—Mantle rock transported and deposited by rivers is called *alluvial mantle rock.*
2. *Aeolian.*—Mantle rock transported and deposited by wind is called *aeolian mantle rock.*
3. *Glacial.*—Mantle rock transported and deposited by ice is called *glacial mantle rock.*
4. *Colluvial.*—Mantle rock transported and deposited by gravity is called *colluvial mantle rock.*

III. Reasons for Deposits

A. The ability of wind or water to carry soil depends upon its velocity. Anything which checks the velocity of wind or water tends to cause it to deposit some part of its load.

B. Ice necessarily deposits its load when it melts.

IV. Sorting Action of Water

A. Quiet water deposits sediment in horizontal layers. The heaviest particles settle to the bottom first; the finest particles last. A perfect gradation thus results from top to bottom, with the finest particles lying on top.

B. Running water tends to deposit sediment assorted horizontally. The heaviest particles are deposited first, or farthest up-hill; the finest particles are carried farthest and deposited last. Alluvial soil is therefore assorted according to the fineness of the particles. Some examples of this action are given in the following section.

From PHYSIOGRAPHY FOR HIGH SCHOOLS, *Henry Holt & Co.*

FIG. 45.—LONGITUDINAL SECTION AND PROFILE OF AN ALLUVIAL FAN

V. Alluvial Deposits

A. *Fans and Cones.*—When a stream leaves a steep slope, such as a ravine, and enters a region of more gentle slope, its velocity is checked and it therefore deposits a portion of its load. The coarsest material is deposited first, thus building up a fan- or cone-shaped deposit having irregular stratification. Such a deposit is called an *alluvial cone* or *fan.*

B. *Deltas.*—When a river enters a lake or some other body of water, its velocity is checked and it therefore deposits the greater part of its load. When this deposit is built up to the surface, it forms an

extension of land projecting into the body of water. Such a deposit is called a *delta.*

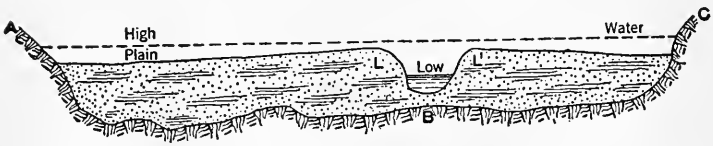
Note.—Deltas are found at the mouths of the Mississippi and the Nile.

From PHYSIOGRAPHY FOR HIGH SCHOOLS, *Henry Holt & Co.*

FIG. 46.—LONGITUDINAL SECTION AND PROFILE OF A DELTA

C. *Flood Plains.*—When a river overflows its banks, the velocity of the water is checked and it therefore deposits a portion of its load, forming a nearly level plain, called a *flood-plain.* A flood-plain is irregularly stratified and is higher near the river than farther back. It forms a natural levee along the bank of the river and tends to form swamps, called *back swamps,* at some distance from the river.

Note.—Flood-plains are found along the lower Mississippi River.



From NEW PHYSIOGRAPHY, *D. C. Heath & Co.*

FIG. 47.—CROSS-SECTION OF A FLOOD PLAIN

D. *Lacustrine Plains.*—The bed of an old lake, which was partly filled with sediment and is now dry, forms a nearly level plain, called a *lacustrine plain.*

Note.—Lake Bonneville in Utah and Lake Agassiz in South Dakota and Minnesota are former lakes which dried up and whose beds are now very fertile lacustrine plains.

VI. Aeolian Deposits.—Aeolian deposits are assorted, but less perfectly than alluvial deposits.

A. *Sand Dunes.*—Sand dunes are hills built up by wind-blown sand. They frequently migrate, and are steeper on the leeward side than on the windward side. Sand dunes are common in deserts and along the seashore.

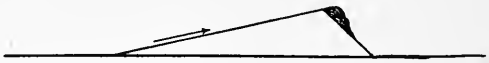


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FIG. 48.—DIAGRAM OF A SAND DUNE (The arrow shows the direction of the wind)

B. *Loess.*—There are deep deposits of wind-blown soil, called *loess,* in Kansas, Nebraska, and other western states in the United States.

C. *Volcanic Dust.*—Ancient Herculaneum and Pompeii were buried by wind-blown volcanic dust.

VII. Glacial Deposits.—Deposits left by glaciers are not assorted, and are called *moraines.* These are discussed in Chapter XXIII.

VIII. Colluvial Deposits.—At the foot of cliffs and other steep slopes, mantle rock which has been pulled down by gravity accumulates and forms colluvial deposits. A colluvial deposit at the foot of a cliff is commonly called a *talus.*

> **Note.**—A talus is found at the foot of the Palisades of the Hudson River.

IX. Types of Soil.—According to their texture, soils are classified as *clay, sand* and *loam.*

A. *Clay* consists of very fine particles which adhere to each other when wet. Clay soil absorbs moisture, but does not allow moisture to drain through it.

B. *Sand* consists of comparatively coarse particles which do not adhere to each other when wet. Sand permits moisture to drain away freely from it.

C. *Loam* is a mixture of sand, clay and humus. It is the best type of soil for agricultural purposes. It is easily worked and holds moisture, but permits an excess of moisture to drain away from it.

X. Humus.—Humus is a dark-brown or black substance found in or on the ground. It is produced by the partial decay of vegetable matter in the presence of a limited supply of air. Humus adds greatly to the fertility of soil. Top soil contains a large percentage of humus.

QUESTIONS

1. (a) What is the origin of mantle rock? (b) State four ways in which mantle rock may be transported and deposited. (c) What is each deposit then called?

2. Describe and illustrate the formation of each of the following: (a) delta; (b) alluvial fan; (c) lacustrine plain; (d) sand dune; (e) talus; (f) flood plain; (g) loess.

3. What are the characteristics of a good soil?

4. (a) What is the origin of humus? (b) Discuss its importance in soil.

CHAPTER XIX

GROUND WATER

I. Origin of Ground Water.—Rain water may either evaporate, run off the surface of the soil into streams, or soak into the ground. *Ground water* is that portion of soil water which soaks into the ground.

II. The Water Table.—The lower portion of mantle rock is always saturated with water. The upper surface of this saturated portion is called the *water table.* Since the height of the water table varies with the amount of rainfall, the lowest level reached by the water table over a long period of time is known as the *permanent water table.*

III. Captive Sheets of Water.—Some layers of sedimentary rock, such as clay or shale, are impervious to water. Other layers, such as loose sand or porous sandstone, permit water to percolate through them. Where these layers of rock come to the surface, it is possible for rain to soak in and saturate a porous layer lying between two impervious layers, thus forming a *captive sheet of water.*

IV. Wells

A. *Farmer's Well.*—A well dug into mantle rock below the permanent water table always provides a supply of water. Such a well is known as a *local,* or *farmer's well* (Fig. 49).

B. *Artesian Well.*—An artesian well is one which is drilled through impervious layers of sedimentary rock until a captive sheet of water is reached (Fig.

50). Since water seeks its own level, water will flow out of the well of its own accord only if the top of the well is below the level of the water in the captive sheet. Otherwise, the water has to be pumped.

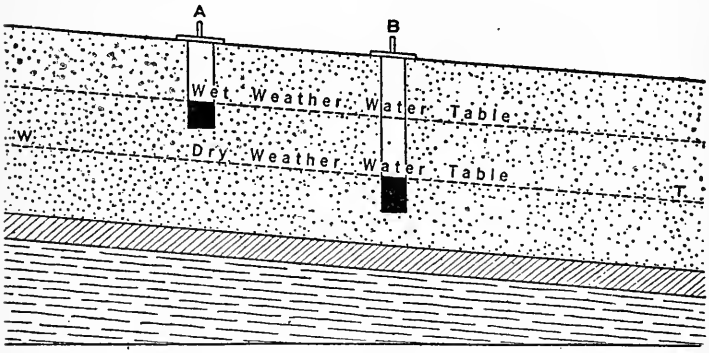

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FIG. 49.—FARMERS' WELLS

(Well *A* will run dry in summer. Well *B* has a permanent supply of water.)

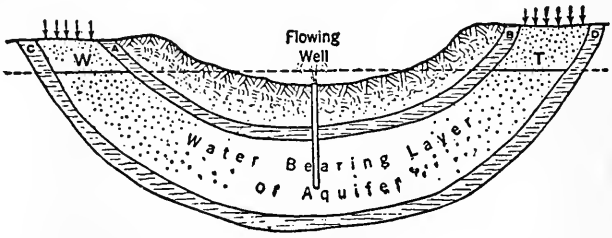

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FIG. 50.—AN ARTESIAN WELL

Note.—At Atlantic City, New Jersey, artesian wells, more than 800 ft. deep, supply water that fell as rain many miles in the interior. In the desert regions of the southwestern states artesian wells are used to supply water for irrigation.

V. Springs.—When ground water finds its way to the surface in sufficient quantity to cause a stream, it forms a *spring*. This sometimes happens on a hillside or slope where an impervious layer under porous mantle rock crops out (Fig. 51), or where a crack in the bed rock leads to a captive sheet of water.

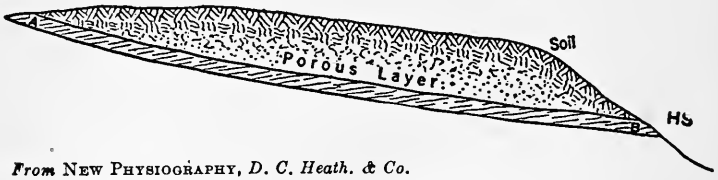

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FIG. 51.—A HILLSIDE SPRING

VI. Hot Springs.—When ground water comes from a great depth, or from the neighborhood of hot lava, a *hot spring* is formed. Since hot water is a better solvent than cold water, the water of such springs has a large mineral content. These minerals usually have curative properties.

> **Note.**—Hot springs are found at Sulphur Springs, Va.; Hot Springs, Arkansas; Bath, England; and Vichy, France. These places are now health and pleasure resorts.

VII. Geysers.—Geysers are springs of hot water that erupt more or less regularly. They are found in Yellowstone Park, Iceland, and New Zealand.

VIII. Deposits Around Hot Springs.—As the water of a hot spring or a geyser cools, it loses its ability to hold minerals in solution and therefore deposits them around the spring. Basins and other forms are thus built, often of great beauty.

IX. Deposits in Veins.—Cracks in the bed rock tend to become filled with mineral matter deposited by ground water. This is particularly true where the hot water rose to the

surface from great depths and cooled. This accounts, in many cases, for the presence of veins in rock and for the presence of valuable ores in veins.

> **Note.**—Precipitation due to chemical action is another cause of deposits.

X. Formation of Caves.—Ground water containing carbon dioxide in solution readily acts on limestone, dissolving it. In many limestone regions large caves have been formed by this action.

> **Illustrations.**—The Mammoth Cave in Kentucky and the Luray Cave in Virginia.

XI. Stalactites and Stalagmites.—When water drips from the ceiling of a cave, some of it evaporates and leaves a deposit of mineral matter, largely limestone. These deposits gradually form *stalactites,* which hang down like icicles. Under the stalactites, similar projections, called *stalagmites,* rise from the floor. When stalagmites and stalactites meet, pillars are formed.

XII. Capillary Action.—Above the water table, the soil is kept moist by capillary action. This makes it possible for the roots of plants to obtain the water which they need, even during a dry spell.

XIII. Economic Importance of Ground Water.—Ground water

A. Furnishes water to wells and springs.

B. Furnishes water to plants by capillary action.

C. Furnishes a steady supply of water to rivers so that they do not run dry between rains.

D. Dissolves mineral matter out of the soil, thus furnishing food for plants.

E. Causes deposits of valuable ores.

QUESTIONS

1. In what three ways is rain water disposed of?

2. What is meant by, (a) temporary water table; (b) permanent water table; (c) captive sheet of water?

3. (a) How far down does ground water extend? (b) What keeps the ground moist above the water table?

4. (a) What evidence is there that ground water flows? (b) What causes ground water to flow? (c) Does ground water help degrade the land? Explain.

5. (a) How are caves formed? (b) Why are caves more abundant in limestone regions than in other regions?

6. Distinguish between a *farmer's well* and an *artesian well.*

7. What natural conditions give rise to springs?

8. (a) Account for the formation of hot springs and geysers. (b) Why are deposits found around hot springs?

9. What is the relation between rivers and lakes and the water table?

10. Discuss the economic importance of ground water.

CHAPTER XX

EROSION AND THE GEOGRAPHIC CYCLE

I. Weathering.—Weathering is the gradual disintegration of rock caused by its exposure to the atmosphere. Weathering may be either chemical or mechanical.

II. Chemical Weathering.—Chemical action causes rocks to soften and crumble, or to be rendered soluble. Among the agents of chemical weathering are the following:

A. *Oxygen.*—Oxidation causes many rocks to soften.

B. *Carbon Dioxide.*—When carbon dioxide dissolves in water, carbonic acid is formed. This acid acts chemically on many rocks, forming soluble carbonates.

C. *Living Plants.*—Roots of plants act chemically on rocks, extracting from them elements necessary for plant growth.

D. *Decaying Animal and Vegetable Matter.*—When animal or vegetable matter decays, acids are formed. These acids react chemically with rocks.

E. *Water.*—Water combines chemically with certain constituents of rocks, thus causing the rocks to crumble.

III. Mechanical Weathering.—Rocks are abraded or broken by natural forces. Some agents of mechanical weathering are

A. *Changes in Temperature.*—The rapid heating or cooling of the surface of a rock causes a strain as

a result of unequal expansion and contraction. Fragments of rock are thus broken off.

B. *Freezing and Thawing.*—When water freezes it expands. Rocks are thus broken by the freezing of water in cracks. Alternate freezing and thawing multiplies the effect.

C. *Wind-Blown Sand.*—Wind-blown sand cuts rocks, thus causing them to wear away.

D. *Gravity.*—Gravity aids weathering by causing fragments to fall away, thus allowing the air to come in contact with fresh surfaces.

IV. Corrosion.—Corrosion is the disintegration of rock by chemical action. It is a sub-process in weathering.

V. Corrasion.—Corrasion is the mechanical wearing away of rock by rock fragments carried by wind, water, or ice.

VI. Erosion.—Erosion is the gradual wearing away of the land by weathering and corrasion. The term erosion implies also the transportation and deposition of debris.

VII. Agents of Erosion.—The agents of erosion include those that cause weathering and corrasion. The following table shows the agents of erosion:

Corrasive Agents	*Weathering Agents*
Streams carrying sediment.	Changes in temperature.
Glaciers dragging rock fragments.	Freezing and thawing.
	Roots of plants.
Wind carrying sand.	Oxygen.
Waves carrying sand.	Carbon dioxide.
Gravity.	Rain.

VIII. Effects of Erosion

A. Erosion has caused the formation of mantle rock, thus making life possible.

B. Erosion has carved the surface of the Earth. It has given it its present appearance by digging gullies, ravines, and valleys, with the consequent wearing down of mountains and plateaus and the deposition of the debris in other places.

IX. Land Formerly Under Water.—With perhaps a few exceptions, all of the present land surface was formerly beneath the water of the ocean. There are two strong evidences tending to prove this.

A. Strata of sedimentary rock, which could have been formed only under water, form a large portion of the land.
B. Rock of limestone mountains, when examined with a microscope, is seen to be composed of minute sea shells.

X. Land Rises and Sinks.—The surface of the land is not stable. It is slowly rising in some places and sinking in others. This may be due to

A. The cooling and shrinking of the interior of the Earth and the consequent wrinkling of the Earth's crust.
B. The change of pressure on the interior of the Earth caused by the wearing away of the high lands and the deposition of the fragments on the low lands or in the ocean.
C. Volcanic activity.

XI. The Life History of a Region.—The life history of a region is the history of the changes that took place in the region due to the rising, sinking, and erosion of the land.

XII. The Geographic Cycle.—A geographic cycle is the complete cycle of changes beginning with uplift above sea level and ending with a reduction to sea level by erosion.

XIII. Age of Land Forms.—Land forms are classified as young, mature, or old, according to their condition with respect to erosion.

A. *Young Land Forms.*—A region is said to be young when relief is being intensified by erosion, and slopes are becoming steeper.

B. *Mature Land Forms.*—A region is said to be mature when relief is being lessened by erosion and steep slopes and ruggedness have disappeared.

C. *Old Land Forms.*—A region is said to be old when it has been reduced to a peneplain.

QUESTIONS

1. (a) Distinguish between *chemical weathering* and *mechanical weathering.* (b) Name the principal agents of erosion.

2. Distinguish between *corrosion* and *corrasion.*

3. What are the effects of erosion?

4. What evidence is there that the greater part of dry land was formerly under water?

5. What is meant by (a) the life history of a region; (b) the geographic cycle?

CHAPTER XXI

ORIGIN AND WORK OF RIVERS

I. Origin of Rivers.—Subsequent rains deepen, widen, and lengthen (headward) any gully that has started.

A. When a gully has been dug below the permanent water table, it receives a permanent supply of water from a spring or from seepage, and a *brook* is formed. Brooks, following the path of least resistance (steepest slope), finally join to form rivers.

B. As a general rule, tributaries meet the master stream so as to form acute angles pointing down stream. A tree-like structure is thus formed.

II. Classification of Rivers.—Rivers tend to degrade the land to base level. They are classified as young, mature or old, depending upon the amount of degrading they have accomplished.

A. *Young Rivers.*—Young rivers are characterized by steep slopes, swift currents, and the ability to corrade their beds rapidly. Lakes, rapids, and waterfalls may be present, which give the young river a convex profile. Young rivers have *V*-shaped valleys and few tributaries.

B. *Mature Rivers.*—A river is said to be mature when it has destroyed its rapids, falls, and lakes, and has so adjusted its slope that it is just able to carry its load of rock waste. A mature river has a broad valley, many tributaries, and has begun to meander.

C. *Old Rivers.*—Old rivers are characterized by sluggish currents, wide, flat-bottomed valleys, well-

developed meanders, and oxbow lakes. Their currents cannot carry all of their load, so that a part is deposited, thus tending to raise their beds.

Illustrations.—The head waters of the Mississippi and other large rivers are swift, young mountain streams. The middle course of the Mississippi is mature, and the lower course is old.

III. The Work of Rivers

A. *Drainage.*—Rivers drain away surplus rainfall.

B. *Corrasion.*—Rivers deepen, widen and lengthen (headward) their valleys.

C. *Transportation of Rock Waste.*—Rivers transport mineral matter held in solution, and fragments of rock broken off by corrasion or washed in by surface run-off.

D. *Deposition of Rock Waste.*—Rivers deposit rock waste, forming sand bars, alluvial fans and cones, flood plains, and deltas (Figs. 45, 46, and 47).

E. *Comminution of Rock Waste.*—Rivers grind the fragments they carry, rounding off pebbles and making small fragments still smaller.

IV. Playfair's Law.—*Tributaries are generally swifter and corrade their beds faster than their master stream, but since they cannot dig lower than the level where they join, they meet their master stream at its own level.*

Exception.—Glaciated valleys are often deeper than their tributary valleys, which are therefore left as hanging valleys. In such valleys, tributaries drop down to the level of their master stream as waterfalls.

V. Accidents to Rivers.—Many streams have their normal development interrupted by changes in elevation or in climate, thus causing drowning, rejuvenation, drying up, and other effects.

VI. Drowned Rivers.—The eastern coast of the United States was formerly more elevated than it is at present. The sinking of the coast permitted ocean water to flow up into river valleys, thus drowning them.

> **Note.**—The fiords on the Maine Coast, the Hudson River from New York to Troy, and Chesapeake Bay, are drowned rivers.

VII. Rejuvenated Rivers.—If the basin of an old river is raised so that the gradient of the river is increased, it is again able to degrade its bed and is said to be rejuvenated. It then forms *intrenched meanders, alluvial terraces.* or *water gaps,* according to local conditions.

VIII. Water Gaps.—The Delaware Water Gap and the water gaps of the Susquehanna River are narrow passage-ways through mountains. Their formation is explained as follows:

A. A large region was worn down to a plain. Rivers crossed this plain.

B. The region was elevated, thus forming a plateau having tilted rock strata of uneven hardness.

C. As erosion proceeded, tilted hard layers of rock were left standing as mountain ridges. Valleys formed in the softer layers.

D. The old rivers ran across the tilted strata nearly at right angles to them, cutting broad valleys where the rock was soft and narrow valleys where the rock was hard. These narrow valleys formed water gaps.

IX. How a Valley Is Created.—Rivers either modify their valleys, if they were already formed by mountain-making forces, or they create valleys when they cross a plateau or plain. They accomplish this by downward and lateral corrasion. They are assisted in this process by rain, surface run-off and other agents of erosion.

X. Shape of Valleys.—In general, valleys start with a narrow *V*-shape. They gradually widen as erosion proceeds until their sides have very gentle slopes.

XI. Formation of Waterfalls.—A stream either finds a natural precipice over which it falls, as at the *escarpment* between Lake Erie and Lake Ontario, or it develops a precipice by *differential corrasion,* as at the Great Falls of the Potomac.

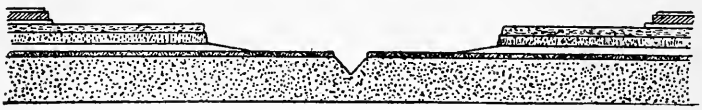

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FIG. 52.—CROSS-SECTION OF THE COLORADO CANYON

XII. Formation of Gorges and Canyons

A. *Gorges.*—A gorge is usually formed by the recession of a waterfall.

Examples.—Niagara Gorge and Ausable Chasm.

B. *Canyons.*—The following conditions are necessary for the formation of a canyon:

1. There must be a plateau in order that the canyon may have length and depth.
2. There must be a comparatively swift stream carrying sediment, so that downward corrasion will be vigorous.
3. There must be a dry climate so that the widening of the valley by rain and surface run-off will be retarded.

Note.—These conditions are met with along the Colorado River and its tributaries. The Grand Canyon in Arizona is the most famous of the canyons found in this region.

XIII. Formation of Meanders.—Meanders are found in the flood-plains of the lower courses of old rivers (Figs. 53-54).

A. The inertia of the water in rivers causes the swiftest current to be on the outside of curves.

B. On the outside of a curve, the river is cutting its bank, leaving it nearly perpendicular; on the inside of the curve, the river is depositing sediment, thus forming a plain.

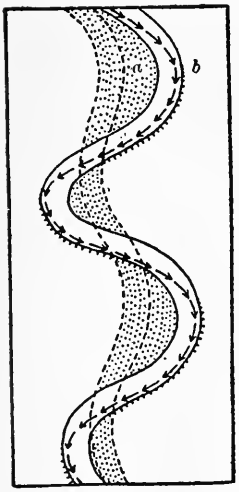

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FIG. 53.—AN EARLY STAGE IN THE DEVELOPMENT OF RIVER MEANDERS

(The dotted portion represents the area over which the river has worked)

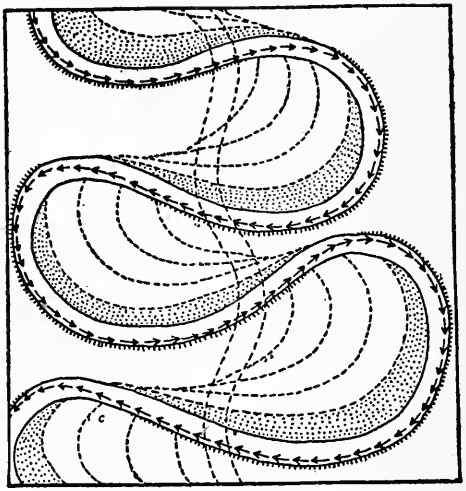

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FIG. 54.—A LATER STAGE IN THE DEVELOPMENT OF RIVER MEANDERS

C. The result is an exaggeration of the curve into the shape of the letter *S*. This type of curve is called a *meander*.

XIV. Formation of a Cut-Off.—As the cutting of the bank continues, two curves approach each other until, finally, the

narrow embankment between is cut away, forming a *cut-off*. The cut-off tends to shorten and straighten the river.

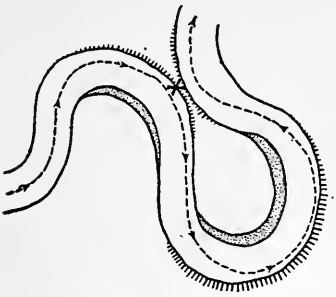

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FIG. 55.—FORMATION OF A CUT-OFF

(The narrow embankment at *X* will soon be cut through)

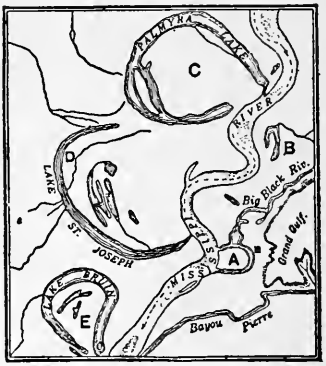

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FIG. 56.—OXBOW LAKES

XV. Development of a Gully

A. When surface run-off flows down a steep slope, it collects in a stream and digs in, forming a narrow, *V*-shaped miniature valley, or *gully*. The material removed is deposited in assorted form at the foot of the gully where the slope is gentler.

B. As the temporary stream in the gully shrinks in volume, its carrying power diminishes and it deposits material along the bottom of the gully, making it flat-bottomed. The finest particles are carried farthest. The deposit in the bottom of the gully is composed largely of coarse material.

XVI. Oxbow Lakes.—The bend of a meander left by a cut-off is gradually shut off from the river by deposits across its ends, thus forming an *oxbow lake*. Such a lake is supplied with ground water by seepage.

XVII. Life History of a River.—Rivers grow from youth to maturity and old age, gradually degrading the land and reducing it to base level. This process may be interfered with by the elevation or depression of the land, or by a change in climate. The work the river has to do is thus either hastened or retarded.

XVIII. Protection from Floods.—The lowlands of a large river may be protected from floods by

A. *Levees.*—These are artificial embankments along the sides of the river to confine the river to its channel.

B. *Dams.*—Dams are built across deep, narrow valleys in the upper courses to hold back flood waters. These dams tend to regulate the flow of water and, incidentally, furnish water power or water for irrigation purposes.

C. *Parallel Channels.*—Additional channels are built along the lower course, parallel to the main channel, connected with it and protected by levees. These channels take care of excess water and prevent floods.

XIX. Economic Importance of Rivers

A. *Drainage.*—Rivers remove surplus rainfall and thus prevent flooding of the land.

B. *Water Power.*—Rivers furnish cheap power, thereby creating great wealth.

C. *Transportation.*—Rivers are great highways of commerce. They furnish the easiest means of travel in the exploration and opening up of new country, and the cheapest means of transporting goods.

QUESTIONS

1. Describe the development of a gully.

2. As a gully grows, at what stage does it develop a permanent stream of water?

3. (a) State Playfair's Law. (b) Describe an exception to this law.

4. (a) What is the life work of a river? (b) How may this work be interrupted?

5. Name and describe four features due to stream erosion.

6. Describe two processes by which streams wear away mantle rock and bed rock.

7. Describe three ways in which streams transport rock material.

8. (a) Discuss the relation between the velocity of a stream and its ability to transport rock waste. (b) What causes a stream to deposit a portion of its load?

9. Compare the conditions that produced Niagara Gorge with those that produced the Colorado Canyon.

10. Describe the formation of, (a) meanders; (b) oxbow lakes; (c) alluvial fans; (d) deltas; (e) flood-plains.

11. (a) Describe three ways in which waterfalls are formed. (b) Give an illustration of each.

12. (a) Describe the life history of a river. (b) Mention accidents that may happen to rivers.

13. Describe three methods used to prevent damage from floods.

14. Discuss the economic importance of rivers.

15. Explain how the Delaware Water Gap was formed.

16. Account for, (a) the tides in the Hudson River at Albany; (b) the formation of the Chesapeake Bay; (c) the fact that the Susquehanna crosses mountains at right angles to their general trend.

CHAPTER XXII

LAKES, FALLS, AND RAPIDS

I. Formation of Lakes.—The following conditions are necessary for the formation of a permanent lake:

A. *A Lake Basin.*—A lake basin is a depression in the land, the rim of which is everywhere higher than the bottom of the depression.

B. *Sufficient Water.*—There must be tributary streams or sufficient rainfall to supply the lake with water, and to offset the loss of water by evaporation and drainage.

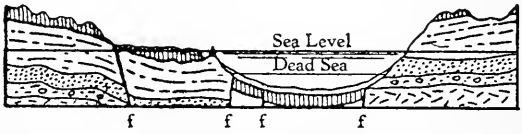


FIG. 57.—CROSS-SECTION OF THE RIFT VALLEY IN WHICH THE DEAD SEA IS LOCATED

II. Formation of Lake Basins

A. *Rift Valleys.*—Sometimes parallel fault planes develop and a long narrow block of rock drops down leaving a rift valley, which may serve as a lake basin.

Note.—Lake Baikal in Siberia, the Dead Sea in Palestine, and Lake Tanganyika in Africa, occupy rift valleys.

B. *Craters.*—The craters of some dormant or extinct volcanoes serve as lake basins.

Illustrations.—Crater Lake in Oregon, and Lake Avernus in Italy.

C. *Glacial Action*

1. Glaciers form lake basins by gouging out river valleys, or by depositing debris across river valleys. Sometimes both actions are combined.
2. Uneven deposits of glacial till leave basins which become filled with ground water by seepage.

Illustrations.—The Finger Lakes in central New York were formed by the deepening of river valleys by glaciers. Lake Ronkonkoma in Long Island was formed in a depression, or *kettle,* left by an uneven deposit of glacial debris, probably due to the subsequent melting of a large mass of ice that was buried in the moraine.

D. *Uplift.*—Lake Superior and the Caspian Sea are the result of the uplift of land masses that now separate them from the ocean.

III. Destruction of Lakes.—Lakes are comparatively short-lived features in the history of a region. The following processes tend to destroy lakes:

A. *Filling.*—Tributaries bring sediment and deposit it in the lake, gradually filling it.

B. *Corrasion of Outlet.*—Outlet rivers corrade their beds, gradually lowering the surface of the lake.

C. *Growth of Vegetation.*—After a lake has been partly filled and drained, conditions become favorable for a rank growth of swamp vegetation, which helps fill in the lake. This action may be seen in bays or at the ends of lakes.

D. *Change of Climate.*—Change of climate from moist to dry may so lessen the supply of water that evaporation will destroy the lake.

Illustrations:

1. The southern end of Seneca Lake in central New York illustrates the process of filling. More than five miles of former lake bed have been filled, and now form a plain.
2. Lake Bonneville in Utah was a great fresh water lake, having an outlet leading to the Snake and Columbia Rivers. A change in climate reduced the supply of water, and evaporation gradually lowered the level of the lake until only a remnant, the present Great Salt Lake, was left.
3. Many small lakes in New Jersey have become productive cranberry bogs.

IV. Economic Importance of Lakes

A. They regulate the volume of water in rivers and therefore prevent floods, furnish steady water power, and aid the continuous navigation of rivers.

B. They conserve rain water for use in irrigation, and for use in homes for drinking, cooking and washing. They also act as great settling basins to clarify this water. Many artificial lakes have been constructed for these purposes.

C. They form highways of travel and commerce.

D. They furnish an abundance of food.

E. Their immediate vicinities serve as health and recreation resorts.

F. Large lakes modify the climate of the surrounding regions.

Illustrations

1. The Great Lakes furnish a steady supply of clear water to the St. Lawrence River. This river, therefore, is not subject to floods and always has sufficient water for navigation. This is in contrast with the Ohio and Mississippi Rivers, which have frequent floods and whose navigation is interfered with by changes in volume. They are also less attractive because of the turbidity of their waters.
2. The Great Lakes form an excellent highway of commerce between Buffalo at one end and Duluth and Chicago at the other.
3. Lake George and Lake Champlain are health and pleasure resorts visited by many thousands of people every summer.
4. Lake Ashokan in the Catskills is an artificial lake which furnishes water for domestic use in New York City.
5. Roosevelt Dam in Arizona forms an artificial lake whose water is used for irrigation.

FALLS AND RAPIDS

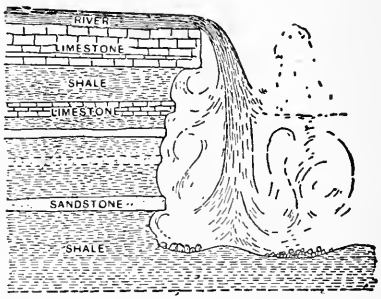
I. Waterfalls and Rapids.—Waterfalls and rapids are found in young regions where erosion has not progressed very far, since they are temporary features which erosion eliminates.

II. Classification.—Waterfalls and rapids are classified as *consequent* or *subsequent*, according to whether their streams found a precipice already made for them, or developed their own. They are sometimes classified also as the *Niagara type*, the *vertical dike type*, etc., according to the nature of the rock formation involved.

III. Niagara Falls

A. This is called a *consequent* falls, since the Niagara River found a precipice in its path over which to tumble.

B. The rock formation consists of horizontal (or nearly so) layers of hard limestone, sandstone, and shale. The top, or cap, layer consists of hard limestone, about 60 feet thick, with less resistant layers of shale, limestone, and sandstone beneath. The drop is 160 ft.



From PHYSIOGRAPHY FOR HIGH SCHOOLS, *Henry Holt & Co.*

FIG. 58.—NIAGARA FALLS

C. The falling water dashes against the precipice, carrying rock fragments which cut into the precipice and undercut the top layer.

D. In time, blocks of the top layer fall and thus restore the perpendicular condition. This action causes the falls to recede up stream, leaving a gorge.

IV. The Niagara Gorge.—The Niagara Gorge is about seven miles long and two hundred feet deep. Since the falls are receding about 5 ft. a year, the possible age of the gorge is 7,400 years. Other evidences indicate that formerly the rate of recession was much slower, and that from 25,000 to 50,000 years were required for digging the gorge.

V. Other Falls

A. *The Genesee Falls* at Rochester, N. Y., are due to the same formation that is found at Niagara.

B. *The Falls of St. Anthony* at Minneapolis are, like Niagara Falls, due to a hard layer of limestone with soft rock beneath.

C. *The Shoshone Falls* of the Snake River in Idaho are due to a horizontal sheet of hard lava which overlies less resistant rock.

D. *The Yosemite Falls.*—The Yosemite Valley has been cut deep by an old glacier. The Yosemite River enters the valley by tumbling over its very steep side, forming a waterfall 2,600 ft. high.

VI. The Fall Line.—The line where the Coastal Plain joins the Piedmont Plateau of our Atlantic Coast States is marked by falls and rapids. This line is known as the *Fall Line.*

A. These falls and rapids are caused by the hard crystalline rocks of the Piedmont Plateau which meet the softer sedimentary rocks of the Coastal Plain.

B. They include the falls of the Delaware at Trenton, the Schuylkill Falls at Philadelphia, the James Falls at Richmond, the Congaree Falls at Columbia, and the Savannah Falls at Augusta.

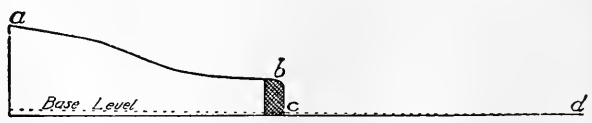


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FIG. 59.—VERTICAL DIKE (The dike at *b* causes a temporary waterfall.)

VII. Vertical Dikes.—In the Cascade Mountains of Washington and Oregon, there are numerous vertical dikes composed of basalt. These rocks are harder than the adjacent rock and cause temporary falls which do not recede up stream like those of the Niagara type.

QUESTIONS

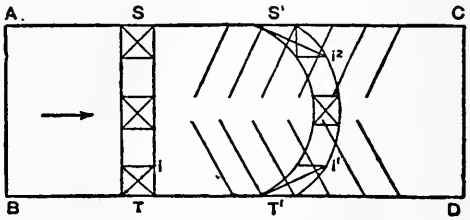
1. Describe five ways in which lakes may be formed.
2. Describe four ways in which lakes may be destroyed.
3. Explain how each of the following lakes was formed: (a) The Finger Lakes, (b) Lake Baikal, (c) Lake Superior, (d) Lake Erie, (e) Lake Ronkonkoma, (f) Lake Avernus, (g) Lake Tanganyika.
4. Explain why the St. Lawrence River has clear water and no floods, while the Mississippi River is muddy and is subject to floods.
5. Discuss the economic importance of lakes.

CHAPTER XXIII

GLACIERS

I. Glaciers.—A glacier is a large mass of ice which has been formed on land where more snow falls than melts. It moves slowly down a slope or over a large area.

II. Formation of Glaciers.—Successive freezing and thawing change the accumulated snow to granular ice, called *névé*. The pressure exerted by upper layers changes the lower layers to ice.



From New Physiography, *D. C. Heath & Co.*

Fig. 60.—Diagram Showing the Movement of a Glacier and the Formation of Oblique Crevasses

(The pattern across the ice at *ST*, marked out by stakes, becomes, a few weeks later, curved at *S'T'*.)

III. Why Glaciers Move.—Gravity is the primary cause of the motion of glaciers. Another cause is pressure, which melts the ice at some point, thus permitting a shifting in the position of the glacier, with consequent change in pressure, and refreezing. These alternate freezings and thawings result in a down-grade creeping of the glacier.

IV. Rate of Motion of Glaciers.—Glaciers move very slowly as compared with rivers. Of those whose rate of motion has been measured, few advance more than 2 ft. a day. Like

rivers, glaciers move faster in the center than at the sides or bottom.

Note.—In Switzerland, glaciers advance from 1 or 2 in. to 4 ft. a day; in Alaska, 7 ft.; in Greenland, 50–60 ft., and occasionally 100 ft. a day in summer.

V. Types of Glaciers

A. *Alpine Glaciers.*—Alpine glaciers are formed in mountain valleys above the snow line, and are therefore sometimes called *valley glaciers.* These glaciers are small, are confined to valleys, and move more rapidly than continental glaciers. They extend for a considerable distance below the snow line to where the supply of ice from above just meets the loss caused by evaporation and melting.

Examples.—Muir Glacier in Alaska, and Mer de Glace in Switzerland.

B. *Continental Glaciers.*—Continental glaciers are vast fields of snow and ice covering large areas without regard to hills or valleys. They are sometimes thousands of feet thick and move very slowly toward the sea. Sometimes a mountain peak projects through the ice sheet, forming an island (*nunatak*) in a sea of ice.

Note.—Great ice sheets cover Greenland and the Antarctic continent.

VI. The Work of Glaciers

A. Drain away excess snowfall.
B. Corrade their beds.
C. Transport rock waste, finally depositing it.

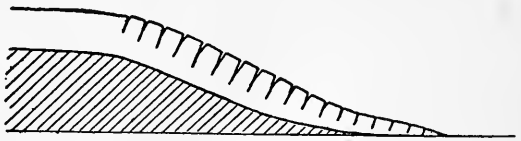
VII. Effects of Glaciers

A. Gouge out *V*-shaped valleys, changing them to a *U*-shape.

B. Cause great parallel scratches in the bed rock (*striae*) by dragging boulders along the rock surface.

C. Grind rock to a fine powder (*rock flower*), and polish the surfaces over which they pass.

D. Continental glaciers round off the tops of hills and mountains.



From PHYSIOGRAPHY FOR HIGH SCHOOLS, *Henry Holt & Co.*

FIG. 61.—TRANSVERSE CREVASSES DEVELOPED BY ICE PASSING OVER A CONVEX PORTION OF ITS PATH

VIII. Crevasses.—Crevasses are cracks in a glacier caused by unequal movements of the ice. There are three types of crevasses.

A. *Transverse Crevasses.*—Transverse crevasses appear when the ice passes over a convex portion of its path, and disappear when the ice is compressed in a concave portion.

B. *Oblique Crevasses.*—Oblique crevasses are formed by the more rapid movement of the center of the glacier than of the sides.

C. *Longitudinal Crevasses.*—Longitudinal crevasses are formed when a glacier spreads out because its valley widens.

IX. Moraines.—The rock waste transported and deposited by glaciers is called *moraine.*

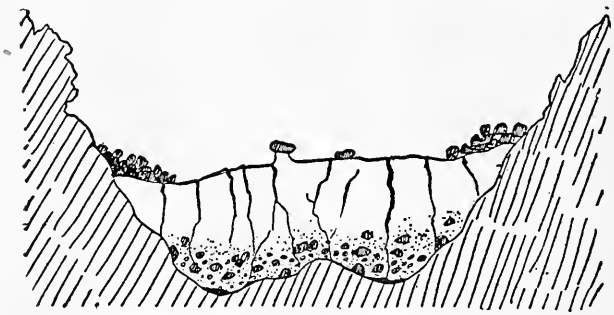
A. *Lateral Moraine.*—Lateral moraine is the debris carried along the sides of a valley glacier.

B. *Medial Moraine.*—When two glaciers join, the inside lateral moraines join to form a medial moraine.

C. *Ground Moraine.*—Ground moraine is the debris carried underneath the glacier.

D. *Terminal Moraine.*—Terminal moraine is the unassorted material deposited at the end of a glacier when it melts.

E. *Glacial Till.*—Glacial till is the unassorted material spread over the ground when the glacier retreats.



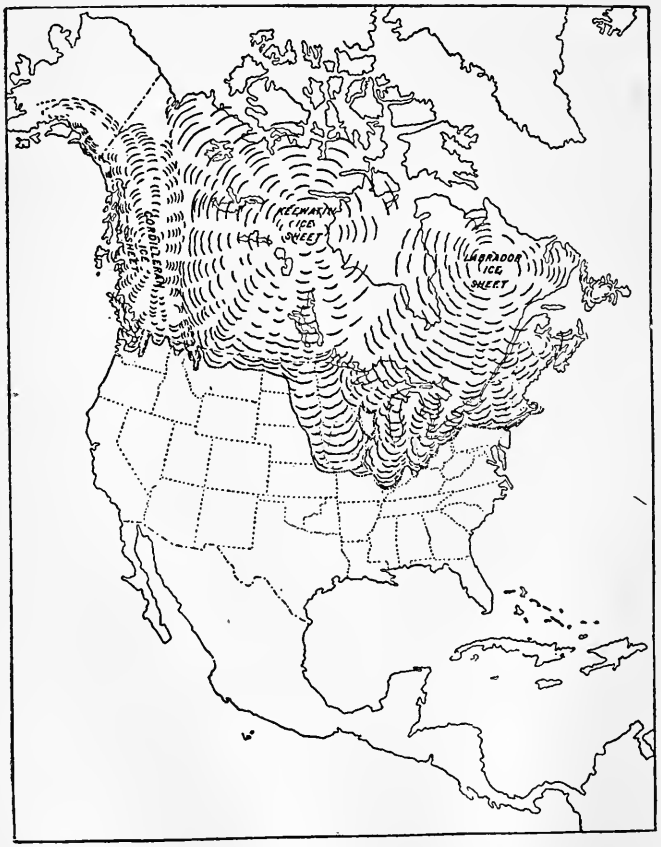
From New Physiography, *D. C. Heath & Co.*

Fig. 62.—Cross-section of a Glacier, Showing Lateral and Ground Moraine, Crevasses, and Ice Table. (Walther.)

X. Icebergs.—When a glacier reaches the sea, great masses of ice break off from it and float away. These floating masses of ice are called *icebergs.* Large icebergs measure from a quarter to a half mile across and project 100–200 ft. out of water. It should be remembered that when ice floats, nine-tenths of it is submerged, and hence the visible portion of an iceberg represents only one-tenth of the total mass of the iceberg.

XI. Icebergs and Navigation.—Icebergs are one of the most serious hazards of ocean travel, since they are frequently surrounded by fog and are then invisible. A great number of icebergs are brought down by the cold Labrador

Current from Greenland to the vicinity of Newfoundland, are caught by the warm Gulf Stream, and are carried some distance toward the northeast before they melt. They are thus carried into the path of great ocean liners and sometimes cause serious wrecks.



From PHYSIOGRAPHY FOR HIGH SCHOOLS, *Henry Holt & Co.*

FIG. 63.—EXTENT OF THE ANCIENT CONTINENTAL GLACIER IN NORTH AMERICA

XII. The Ice Age.—There are evidences that a continental glacier formerly covered the northern part of North America and Europe. Its disappearance left

A. *Terminal Moraines.*—A line of moraines extends across the United States from Long Island and Northern New Jersey through Pennsylvania to Illinois. This line continues toward the northwest, ending at Puget Sound.

B. *Outwash Plain.*—South of this line is a great outwash plain of assorted gravel, sand, and clay.

C. *Glacial Effects.*—North of this line are innumerable lakes, glaciated valleys, erratic boulders, striae, polished rock surfaces, and deposits of glacial till. Below this line these evidences are lacking.

XIII. The Great Lakes.—During the retreat of the ice sheet the Great Lakes were much larger than they are at present. The outlet toward the northeast was blocked with ice, and drainage was toward the south through the Wabash and Illinois Rivers. As the ice retreated, an outlet was opened through the Mohawk Valley, and later a still lower outlet was opened through the St. Lawrence River. This caused a lowering of the lakes to their present level.

XIV. Economic Effects of the Ice Age

A. In some places, as in New England, the glacial till, consisting of sand, gravel, and rocks of various sizes, made agriculture difficult and unprofitable. This was somewhat compensated for by the waterfalls which supplied water power for manufacturing.

B. In other places, as in the valley of the Red River of the North and on the borders of the Great Lakes, the soil is very fertile lacustrine soil which was left by the shrinking of the lakes as the ice retreated.

C. In general, the ancient glaciers added to the beauty of the land by rejuvenating it, thereby providing lakes and waterfalls. On the whole, they probably did more good than harm.

QUESTIONS

1. (a) What is a glacier? (b) Where are glaciers found? (c) Distinguish between *alpine glaciers* and *continental glaciers.*

2. Compare rivers with glaciers as to (a) rate of flow; (b) ability to transport rock waste; (c) effect on shape of valleys; (d) character of deposits; (e) ability to drain their valleys.

3. Describe four effects of glacial action.

4. Describe five kinds of glacial deposits.

5. What evidences are there that northern United States was formerly covered with ice?

6. Discuss the economic effects of the Ice Age.

CHAPTER XXIV

PLAINS

I. Plains.—A plain is a broad, level area of land, usually lower than adjacent lands, at least on one side.

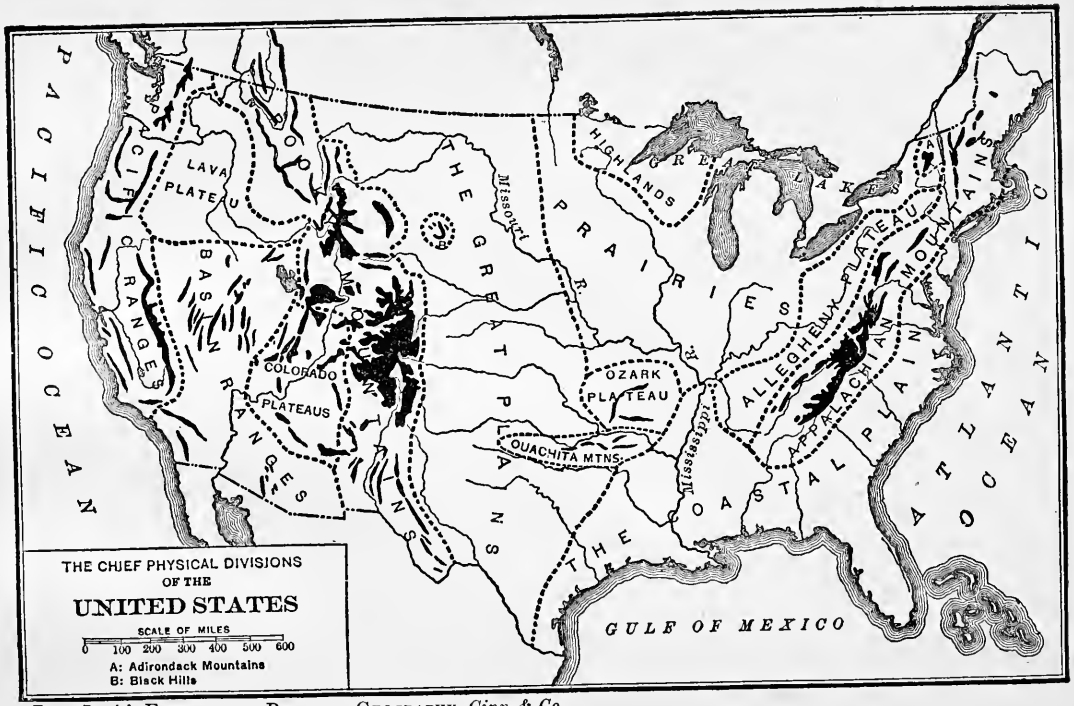
II. Origin of Plains.—Plains were formed either by deposition or erosion. Some plains are an elevated portion of the ocean floor, others were deposited by lakes or rivers, and still others were formed by the erosion of mountains or plateaus.

III. Height Above Sea Level.—Plains differ widely in elevation. They may be a few feet or many thousands of feet above sea level. They are plains by contrast, rather than by position. They also differ greatly in size, origin, fertility, etc.

IV. Types of Plains

A. *Plains of Deposition*	*Examples*
1. Marine plains	The Atlantic Coastal Plain
2. Lacustrine plains	The valley of the Red River of the North
3. Alluvial plains	The Delta of the Mississippi
4. Glacial till plains	Northern Ohio
5. Outwash plains	Southern Long Island

B. *Plains of Erosion*	*Examples*
1. Peneplains	Southern New England
2. Glacial plains	The Highlands of Quebec



From Davis's Elementary Physical Geography, *Ginn & Co.*

Fig. 64.—Important Plains, Plateaus, and Mountains of the United States

V. Marine Plains.—A marine plain is an elevated portion of the ocean floor. Its strata, which remain nearly horizontal, were deposited under water and later were raised, becoming dry land. The great interior plain of the United States, and the Atlantic coastal plain, were formed in this manner.

VI. The Atlantic Coastal Plain.—This marine plain is a narrow belt of low, nearly level land, extending from New Jersey to Mexico. It was so recently raised above the sea that its streams are young, and large tracts are undrained. The underlying strata slope gently from the Piedmont Plateau toward and beneath the sea. The outcroppings of these strata form belts, which differ greatly in the texture and fertility of their soil.

VII. Types of Belts

A. Next to the Piedmont Plateau, there is a belt of clay soil. In some places, this soil is used for general agricultural purposes; in others, for making brick and porcelain.

B. Next to the clay belt is a belt of sandy soil. This soil is very poor for agricultural purposes but supports large pine forests, which furnish lumber, rosin, tar, and turpentine.

C. Between the pine forests and the sea is a belt of rich soil. The higher portion of this soil is suitable for tobacco and cotton growing; the lower, swampy portion is suitable for rice growing.

> **Note.**—The large towns on the coastal plain are situated either at the mouths of rivers and heads of bays, where there are good harbors, or at the fall line where there is water power for manufacturing.

VIII. Lacustrine Plains.—Lacustrine plains are composed of alluvial soil which settled in the quiet water of a lake.

A. In some cases, lacustrine plains are found around the shores of lakes that were formerly much larger, as around the Great Lakes, Lake Winnipeg, and Great Salt Lake.

B. In other cases, lacustrine plains are the beds of extinct lakes such as the many salinas of the southwest.

Note.—A salt plain is called a *salina.*

IX. Lake Agassiz.—Lake Agassiz is the bed of a former great lake of which Lake Winnepeg is the remnant. Its land is very level, but portions of it are covered with salt deposits which render the soil unfit for agricultural purposes. It is a valuable source of salt from which table salt is obtained.

X. The South Shore of Lake Erie.—This is a lacustrine plain which was formed by the earlier and greater lake. The soil is very fertile, and since the climate is tempered by the presence of the lake, it is an excellent fruit-growing region, sometimes called the *Grape Belt.*

XI. Lake Bonneville.—This is the bed of a former great lake of which Great Salt Lake is the remnant. Its land is very level, but portions are covered with salt deposits which render them unfit for agriculture, although valuable as sources of salt from which table salt is refined.

XII. Death Valley.—On the floor of Death Valley, in California, is a lacustrine plain containing valuable deposits of borax and other salts.

XIII. Alluvial Plains.—Alluvial plains include flood plains and deltas. The lower courses of the Nile, Ganges, and Euphrates, in the Old World, and the Mississippi in the New World, have flood plains and deltas. These are very fertile and are capable of supporting large populations.

XIV. Peneplains.—The term *peneplain* means *almost a plain.* It is applied to mountain or plateau country which has been worn down almost to base level. Peneplains are not as level as plains of deposition, since more resistant tilted layers of rock remain as elevated ridges, as in southern New England, or portions of hard horizontal strata remain as *buttes* and *mesas,* as in the great plains east of the Rocky Mountains.

XV. Economic Importance of Plains.—Although many plains are desert regions and are sparsely inhabited, plains are the great agricultural regions of the world and support great numbers of people. As a general rule, the soil of plains is fertile and well-watered. It is easy to construct and maintain roads, canals, and railroads on plains. Many plains touch the sea and have good harbors. Ease of communication and fertility of soil are conditions that favor agriculture, commerce, manufacturing, and the maintenance of a large population.

QUESTIONS

1. (a) What is a plain? (b) Name and illustrate eight types of plains.

2. Describe, (a) the Atlantic Coastal Plain; (b) the lacustrine plain known as the bed of former Lake Bonneville; (c) the Great Plains.

3. (a) Why did Lake Bonneville dry up? (b) What was its former outlet?

4. (a) What is a *salina?* (b) What is the origin of the borax deposits in Death Valley, California?

5. Discuss the economic importance of plains.

CHAPTER XXV

PLATEAUS

I. Definition.—A plateau is a broad, level area whose altitude is conspicuously higher than that of adjacent land or water, at least on one side.

II. Origin of Plateaus

A. Plateaus are formed by the elevation of land to a nearly horizontal position by natural forces.

B. *Fault plateaus* are formed by the elevation of land on one side of a fault plane.

C. *Lava plateaus* are formed by the outpouring of lava.

III. Strata of Plateaus

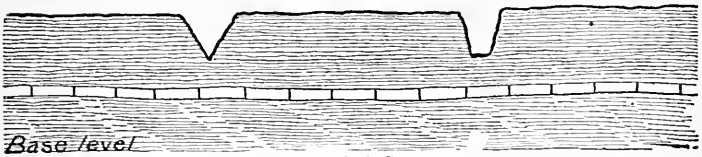
A. In many cases the strata are nearly horizontal, indicating that they were formed by the uplift of a portion of the ocean floor without much distortion of the strata.

B. In other cases, the strata are tilted and warped in such a way as to indicate that erosion had worn a mountainous region down to base level, forming a plain. This plain was then elevated to form a plateau.

IV. Life History of a Plateau.—A plateau passes through the stages of youth, maturity, and old age.

A. As soon as a plateau has been elevated, rivers and other agents of erosion begin the task of reducing it to base level.

B. When maturely dissected by erosion, the plateau has the appearance and many of the characteristics of mountain country. When old, it is no longer a plateau, but a plain.

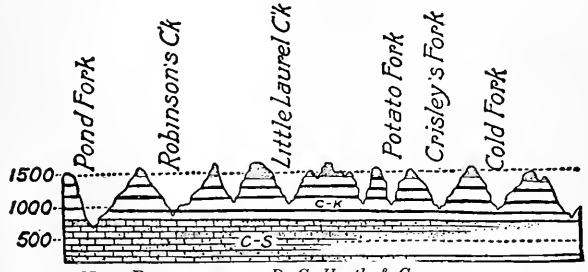


From NEW PHYSIOGRAPHY, *D. C. Heath & Co.*

FIG. 65.—DIAGRAM OF A YOUNG PLATEAU

V. Young Plateaus.—Young plateaus are characterized by a general elevation and levelness of land, except where they are cut by deep river valleys. In a dry climate, these valleys are canyons. In a moist climate, they are deep, *V*-shaped valleys, too wide to be classed as canyons.

Example.—The Colorado Plateau.



From NEW PHYSIOGRAPHY, *D. C. Heath & Co.*

FIG. 66.—CROSS-SECTION OF THE APPALACHIAN PLATEAU NEAR CHARLESTOWN, W. VA. (Scale, 1 in. = 2 miles.)

VI. Mature Plateaus.—Mature plateaus are characterized by hills and valleys, strongly resembling, and commonly called, mountains. The hill-tops, however, form a straight sky-line. A study of the strata gives further evidence

that the region is a dissected plateau. If the strata were horizontal before erosion, they match exactly on opposite sides of a valley.

Example.—The Appalachian Plateau.

VII. Old Plateaus.—Old plateaus are those that have been worn down to plains or peneplains. There is usually sufficient evidence left in the form of *buttes, mesas,* or *monadnocks* to indicate the former altitude. Old plateaus are characterized by their general level condition, old drainage, and the presence of elevations that have resisted erosion.

Example.—The region of buttes and mesas of New Mexico.

From NEW PHYSIOGRAPHY, *D. C. Heath & Co.*

FIG. 67.—DIAGRAM OF AN OLD PLATEAU, SHOWING A BUTTE AND A MESSA

VIII. Mesas, Buttes, and Monadnocks

A. *Mesas.*—A mesa is a broad, flat-topped area, having very steep sides, horizontal strata, and a talus at the foot of the cliffs. Mesas are characteristic of dry-climate plateaus. They owe their origin to the fact that a portion of a horizontal stratum of rock resisted erosion and protected the layers beneath it.

B. *Buttes.*—A butte is exactly the same as a mesa, except that its surface area is very much smaller.

C. *Monadnocks.*—A monadnock is an irregularly-shaped, hard rock formation of volcanic origin, left standing above the general elevation in a mature or old plateau.

IX. The Arizona Plateau.—This is a portion of the Rocky Mountain Plateau, located in the northeastern part of Arizona.

A. It is a typical, dry-climate, young plateau, having an elevation of from 5,000 to 8,000 ft. above sea level.

B. Its nearly horizontal surface is broken up by ranges of mountains formed by volcanic action, and by deep canyons, including the Grand Canyon of the Colorado River. The latter is more than a mile deep and about ten miles wide at the top. There are also mesas and buttes, indicating a former greater altitude.

X. The Appalachian Plateau.—A belt of highlands including the Appalachian Mountains extends from New York to Alabama.

A. The eastern portion of this belt is true mountain country having folded rock strata.

B. The western portion is a mature or dissected plateau, which is distinguishable from the eastern portion by its horizontal strata and even sky-line.

1. This is a well watered and forested plateau, rich in coal, iron, oil, and gas.

2. It has been easy to discover the mineral resources in this region because erosion uncovered them.

3. It has valuable water power, and some of its valleys are broad enough to furnish good locations for farms.

XI. The Piedmont Plateau.—The Piedmont Plateau lies between the Appalachian Mountains and the Coastal Plain. It is an elevated peneplain.

A. The rejuvenated rivers have cut deep valleys, making this plateau a hilly country. The hill-tops form a nearly level sky-line, except for an occasional monadnock which rises above the general level.

B. The Piedmont Plateau has a deep, fertile, residual soil and abundant rainfall. It is a splendid agricultural section. Great cotton and tobacco plantations are located in this region.

XII. The East African Plateau.—This plateau is a region of moderate elevation, located in the tropical section of East Africa.

A. It is a young plateau, broken by ranges of mountains.

B. It is remarkable for its healthful climate, rainy and dry seasons, abundant animal life, and deep valleys.

C. It contains two nearly parallel rift valleys of tremendous extent, partly occupied by long, narrow lakes. One of these, Lake Tanganyika, is the longest in the world.

XIII. Economic Importance of Plateaus.—In general, plateaus have a drier climate and other conditions which are less favorable for agriculture than lowlands. Deep valleys make communication difficult, and plateaus are therefore more sparsely settled than plains. On the other hand, some plateaus are valuable for their healthfulness of climate, forests, water power, and mineral resources.

QUESTIONS

1. What is a *plateau?*

2. Compare plains with plateaus as to, (a) origin; (b) general levelness; (c) suitability for agriculture; (d) inhabitability.

3. What are the characteristics of, (a) young plateaus; (b) mature plateaus; (c) old plateaus?

4. What are (a) buttes; (b) mesas; (c) monadnocks?

5. Describe, (a) the Arizona Plateau; (b) the Piedmont Plateau; (c) the Appalachian Plateau.

6. Discuss the economic importance of plateaus.

CHAPTER XXVI

MOUNTAINS

I. Origin.—The elevation of mountains is due to natural forces in the interior of the Earth, and their form is due to the work of running water and other agents of erosion. Although we do not know with certainty the origin of the internal forces of the Earth that elevate mountains, we may conjecture that

A. The removal of rock material from elevations and its deposition in the sea cause changes of pressure on the interior of the Earth which result in the movement of surface layers.

B. The cooling and consequent shrinking of the interior of the Earth cause the surface layers to wrinkle. This wrinkling and the consequent folding and faulting of the upper layers give rise to mountains.

II. Definitions

A. *Mountain.*—A mountain is a portion of land having a comparatively great elevation and a small summit area.

B. *Peak.*—A peak is a mountain having a single sharp summit, such as Pike's Peak and Mt. Everest.

C. *Ridge.*—A ridge is a mountain having a long narrow summit.

Examples.—Peter's Mountain and Blue Mountain in Pennsylvania.

D. *Mountain System.*—A mountain system consists of a group of mountain folds made by natural mountain-making forces and forming a closely related group.

Examples.—The Himalayas, the Rocky Mountains, the Andes Mountains.

E. *Mountain Range.*—A mountain range is a small mountain system or a subdivision of a large mountain system.

Examples.—The Adirondacks, the Cascades, the Coast Range.

F. *Mountain Chain.*—A mountain chain is a long group of related ranges.

Example.—The Rocky Mountain Chain.

G. *Cordillera.*—A cordillera is a group of mountain systems.

Example.—The cordillera of western North America includes four systems: the Coast Range, the Sierra Nevadas, the Basin Range, and the Rocky Mountains.

From PHYSIOGRAPHY FOR HIGH SCHOOLS, *Henry Holt & Co.*

FIG. 68.—CROSS-SECTION OF A PORTION OF THE JURA MOUNTAINS

III. Types of Mountains.—Mountains are classified according to their structure or manner of formation as follows:

A. *Folded Mountains.*—Folded mountains are formed by the warping of the Earth's crust. Some are *simply* folded; others are *complexly* folded.

Examples.—The Jura Mountains in Switzerland are simply folded; the Appalachian Mountains in Virginia are complexly folded.

B. *Fault Mountains.*—Fault mountains are formed by the faulting and tilting of great blocks of rock strata.

Examples.—The mountains of the Great Basin, Utah; the Block Mountains in Oregon; the Sierra Nevadas.

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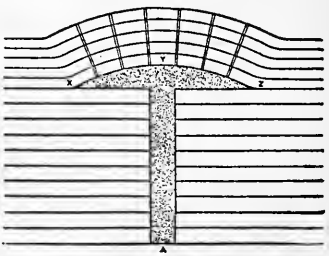
FIG. 69.—FAULT MOUNTAINS OF THE GREAT BASIN

C. *Dome Mountains.*—Dome mountains are formed by intrusions of lava into rock strata, which cause the upper layers to bulge and form domes.

Examples. — The Henry Mountains in southern Utah; the Orange Mountains in New Jersey; the Black Hills in Wyoming and South Dakota.



From NEW PHYSIOGRAPHY, *D. C. Heath & Co.*

FIG. 70.—FORMATION OF DOME MOUNTAINS BY VOLCANIC INTRUSION

D. *Volcanic Mountains.*—Volcanic mountains are formed by extrusions of lava. Usually, a cone is formed around a central vent.

Examples.—Mt. Hood in Oregon; Mt. Pococatapetl in Mexico; Mt. Vesuvius in Italy.

E. *Mountains of Erosion.*—Mountains of erosion are formed by the dissection of a plateau by running water and other agents of erosion. A mature plateau has the appearance and many of the characteristics of true mountains.

Examples.—The Catskill Mountains in New York; the Appalachian Mountains in West Virginia.

IV. The Life History of Mountains.—True mountains, formed by folding of rock strata, rise slowly over long periods of time.

A. As they rise, running water and other agents of erosion are constantly wearing them down so that they never reach their theoretical height.

B. After a time, rising ceases, but denudation continues until the entire region has been reduced to base level. This cycle may be interrupted by a new period of rising, or it may go on to completion. There is abundant evidence that the Earth is very old and that its surface has been worked over many times.

C. Mountains pass through three stages: youth, maturity, and old age.

1. *Youth.*—Young mountains are characterized by great elevation and ruggedness. Lakes and waterfalls are present and valleys are *V*-shaped.

   Examples.—The Rocky Mountains; the Alps; the Himalayas.

2. *Maturity.*—Mature mountains are characterized by moderate elevation and moderate ruggedness. Lakes and waterfalls are absent, except where glacial action has partly rejuvenated the region. Valleys are *V*-shaped but are wide in comparison with those of young mountains.

   Examples.—The mountains of northern England, Scotland and Norway; the Adirondacks; the Green Mountains.

3. *Old Age.*—In old age, mountains are well worn

away and only a peneplain is left. The peneplain is characterized by low hills and the absence of lakes and waterfalls, except where rejuvenated by glacial action. The presence of monadnocks and tilted layers of rock strata give evidence of former elevation.

Examples.—The peneplains of southern New England and the Piedmont Belt.

V. Mountains as Barriers.—In the past, mountains served as effective barriers against the migration of plant and animal life, both because of the steepness of the slopes and the low temperature of the higher altitudes. In modern times, man has partly overcome these barriers by his inventiveness and engineering skill.

VI. Anticlines and Synclines.—In the case of folded mountains, the wave form caused by lateral pressure consists of an anticline and a syncline.

A. An *anticline* is an arched upfold of rock strata, analogous to the crest of a wave.

B. A *syncline* is an arched downfold of rock strata, analogous to the trough of a water wave.

Note.—A monocline is a tilted rock stratum, not a part of a wave form.

VII. Competent and Incompetent Folds.—Sometimes rock strata are crumpled by the great lateral pressure to which they are subjected.

A. *Competent folds* are those which are not crumpled by lateral pressure.

B. *Incompetent folds* are those which are crumpled by lateral pressure.

VIII. Dip and Strike

A. *Dip.*—The angle which a rock stratum makes with a horizontal plane is called the *dip.*

B. *Strike.*—The direction taken by a horizontal line drawn on a rock stratum at right angles to the dip is called the *strike.*

IX. The Jura Mountains.—The Jura Mountains, lofty mountains on the border of Switzerland, are typical of *simply* folded mountains. A study of the rock strata reveals a remarkably even folding and indicates that erosion has removed thousands of feet of rock from the tops of the anticlines.

From PHYSIOGRAPHY FOR HIGH SCHOOLS, *Henry Holt & Co.*

FIG. 71.—CROSS-SECTION OF A PORTION OF THE APPALACHIAN MOUNTAINS

X. The Appalachian Mountains

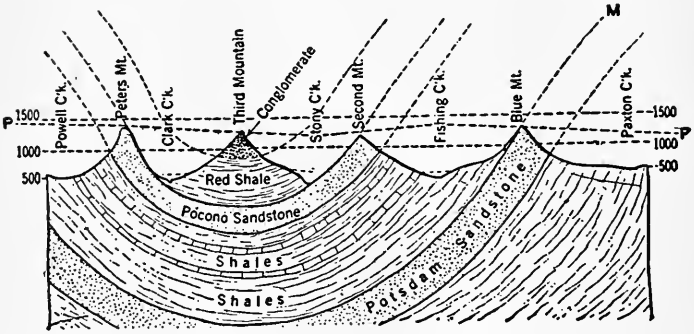
A. *The Eastern Belt.*—The eastern portion of the Appalachian Mountains consists of intensely folded rock strata.

1. In many places there are old faults; in others the weak strata are crumpled.
2. From a study of this region it has been deduced that there were here very high mountains which have been worn down to a plain and then uplifted to form a plateau of considerable elevation.
3. The rejuvenated rivers have cut down into this plateau, leaving the upturned edges of resistant layers as mountain ridges, across which larger rivers flow through water gaps.
4. In many cases, the bottom of a former syncline, having been hardened by compression, resisted erosion and is now the crest of a mountain ridge.

B. *The Western Belt.*—The western portion of the Appalachian Mountains is a dissected plateau. This

is proved by a study of the rock strata which shows that they have never been folded by lateral pressure.

1. The layers are horizontal, and the strata on one side of a valley match those on the other side at the same level.
2. Erosion has carved this plateau into the form of mountains having the ruggedness and other characteristics of true mountain country.



From NEW PHYSIOGRAPHY, *D. C. Heath & Co.*

FIG. 72.—CROSS-SECTION OF THE APPALACHIAN MOUNTAINS NEAR ELLENDALE, PA.

XI. The Sierra Nevadas.—The Sierra Nevadas are comparatively young. They are extremely rugged mountains which were formed by the intense folding and faulting of rock strata. The faulting and slipping of rock strata has produced many steep cliffs and consequent waterfalls. Glaciers on the high peaks serve as sources of water for many mountain streams.

XII. The Block Mountains.—The Block Mountains of southern Oregon were formed by the faulting and tilting of great blocks of rock strata. These mountains have a gentle slope on one side and a very steep slope (fault cliff) on the other. The rock strata form monoclines. Erosion has cut

away the sharp upturned edges of the blocks and partly filled the depressions, thus reducing the angularity of the region.

XIII. The Henry Mountains.—The Henry Mountains of Utah were formed by intrusions of lava.

A. Lava was forced up from beneath and, without breaking through the upper layers, forced these layers to bulge upward, thus forming great dome-shaped mountains.

B. Erosion has removed the upper layers of rock, exposing and carving the intruded lava into its present form.

C. A study of the rock strata in this region indicates that they formerly covered the lava, forming dome-shaped mountains of great altitude.

XIV. The Catskill Mountains.—The Catskill Mountains in eastern New York are not true mountains, but constitute a dissected plateau. A study of the region reveals that running water has cut deep valleys in the plateau, causing the appearance and ruggedness of true mountains. It is easily seen that the strata are horizontal, and that the layers on one side of a valley match those on the other side at the same level.

XV. The Adirondacks and the Rockies.—The Adirondacks are mature mountains of great age.

A. They consist largely of masses of crystalline rock of volcanic origin—the remnants of former dome-shaped mountains of great height.

B. The rock strata which formerly covered these mountains have been removed and deposited elsewhere. These strata can be traced westward to, and partly up the sides of, the Rocky Mountains, but are buried deep under layers of more recent origin. This indicates that the Rockies are much younger than the Adirondacks.

C. The Rockies are, at least in part, dome-shaped mountains of the same nature as the Adirondacks.

D. While the Rockies are very lofty, rugged and largely bare of soil and vegetation, the Adirondacks are moderate in height and ruggedness and are well covered with forest growth. The tops of the Adirondacks have been rounded off by glacial action.

XVI. Economic Importance of Mountains

A. *Forests.*—Mountain slopes are, in general, not suited to agriculture and have therefore been permitted to retain some forest growth. They are now the chief source of supply of timber and many other forest products, such as turpentine, acetone, wood alcohol, rosin, tar, and various gums and balsams.

B. *Minerals.*—Running water, by cutting deep valleys in the folded strata of mountain country, has often exposed valuable deposits of minerals. The mountains of eastern United States furnish great quantities of limestone, marble, granite, coal, and iron. In western United States are found gold, silver, copper, lead, and other valuable minerals.

C. *Agricultural Products.*—Mountain valleys are quite likely to be fertile and productive. The value of agricultural products produced in mountain country often exceeds the value of the minerals dug out. This is true of Colorado, although this state has many valuable gold, silver, and lead mines.

D. *Health and Recreation.*—Because of the healthfulness of their climate and the beauty of their scenery, mountains attract many visitors who come for health and recreation. The Green Mountains of Vermont, the White Mountains of New Hamp-

shire, and the Adirondack Mountains of New York are famous summer resorts.

E. *Water Power.*—Waterfalls are common in mountain country. They are being utilized more and more to develop cheap electric power for use in distant cities. The recent great economic advancement in North and South Carolina is said to be largely due to the development of waterpower.

XVII. Influence of Mountains on History

A. The high mountains surrounding Switzerland enabled a small band of sturdy mountaineers to throw off Austrian rule and maintain their independence for several centuries. Mountains tend to engender sturdiness of body, strength of character, and the love of independence.

B. The Appalachian Mountains, by keeping the early settlers concentrated near the Atlantic Coast, and by holding back the western Indians, enabled the American colonists to gain quickly the strength to throw off English rule and establish an independent nation.

C. For several thousand years, the Caucasus Mountains, the Plateau of Thibet, the Himalayas, and the deserts served to prevent conflict as well as the interchange of ideas between the Chinese and the Indo-European civilizations.

QUESTIONS

1. *Define:* (a) mountain; (b) peak; (c) ridge; (d) range; (e) mountain chain; (f) cordillera.

2. (a) Describe five types of mountains. (b) Give an illustration of each type.

3. *Define:* (a) anticline; (b) syncline; (c) monocline; (d) dip; (e) strike.

4. Describe (a) the Jura Mountains; (b) the Appalachian Mountains (eastern belt); (c) the Appalachian Mountains (western belt); (d) The Sierra Nevadas; (e) the Catskills; (f) the Adirondacks.

5. What are the characteristics of, (a) young mountains; (b) mature mountains; (c) old mountains?

6. Discuss mountains as barriers.

7. Give three illustrations of the effect of mountains on history.

8. Discuss the economic importance of mountains.

CHAPTER XXVII

VULCANISM

I. Volcanoes.—A volcano is a vent in the Earth's crust through which melted rocks rise to the surface. Sometimes steam and noxious gases are also emitted. A large cone is usually built up around the vent, forming a volcanic mountain.

II. Origin of Volcanoes.—Volcanoes are believed to have been originated by forces at work at a depth of several miles in the interior of the Earth.

A. The high temperature in the interior of the Earth is sufficient to melt the most refractory rock, if it were at the surface. The enormous pressure in the interior of the Earth, however, prevents rock from liquefying.

B. This pressure is sometimes relieved, causing the rock material to liquefy and flow. When this melted rock finds its way to the surface, a volcano is formed.

III. Types of Volcanoes.—There are two types of volcanoes, *quiet* and *explosive*. Many volcanoes partake of the characteristics of both types.

A. *Quiet Volcanoes.*—In quiet volcanoes lava rises slowly to the surface and overflows, building up a flat cone. This action is not accompanied by violent explosions.

Examples.—Mauna Loa and Mauna Kea in the Hawaiian Islands.

B. *Explosive Volcanoes.*—In this type of volcano violent explosions occur. Lava is thrown out in the form of dust or in comparatively large masses (*bombs*). Steam and noxious gases are emitted. Often a great cloud, called a *cauliflower cloud,* composed of dust and condensed steam, is seen above the volcano. Frequently the top of the volcano is blown away, and is renewed later by the melted lava that overflows.

> **Examples.**—Vesuvius in Italy, and Krakatoa on an island near Java.

IV. Volcanic Explosions.—Volcanic explosions are caused by pent-up steam and other gases. When hot lava containing these gases comes to the surface, the decrease in pressure causes it to expand suddenly, and an explosion results.

V. Lava.—Lava is melted rock from the interior of the Earth, which has been brought up to the surface by volcanic action. It consists of a great variety of minerals. Decomposed lava, therefore, makes very fertile soil.

> **Note.**—The term lava is also applied to this rock material after it has cooled and solidified.

VI. Structure of Lava.—The structure of lava depends upon the conditions under which it was cooled. If cooled quickly, it has a glassy structure; if cooled slowly, crystals are formed. The slower it cools, the larger the crystals.

A. *Obsidian.*—Obsidian is a dense, glassy form of lava which cooled so rapidly that crystals did not have time to form.

B. *Trap and Basalt.*—These terms are applied to dense forms of lava which contain very small or invisible crystals.

C. *Granite.*—Granite is a form of lava which cooled very slowly and formed comparatively large crystals.

D. *Pumice.*—Pumice is lava which has been rendered light and porous by the expansion of gases which it contained. *Volcanic ash* is pumice which was blown to very small fragments by the violence of the volcanic eruption.

VII. Active, Dormant, and Extinct Volcanoes

A. *Active volcanoes* are those that are in a state of eruption or are known to break out at more or less frequent intervals.

Examples.—Popocatapetl in Mexico; Etna in Sicily; Vesuvius in Italy; and Mauna Loa in Hawaii.

B. *Dormant volcanoes* are those which still show some signs of volcanic activity, such as escaping steam and hot springs, but have not been in eruption for a very long time.

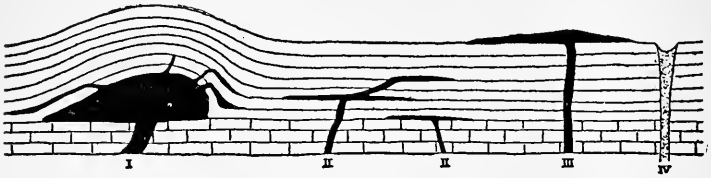
Examples.—Mt. Rainier in Washington; Mt. Hood in Oregon.

C. *Extinct volcanoes* are those which show no signs of present volcanic activity and are believed to be incapable of erupting again.

Examples.—Mt. Shasta in California; Mt. Mazama in Oregon.

VIII. Fissure Eruptions.—Lava sometimes rises through a great fissure instead of through the chimney-like vent of a volcano. In the past, fissure eruptions have occurred on a large scale, and floods of lava have spread over many miles of surface. There is a great lava plateau of volcanic origin in Oregon.

IX. Laccoliths.—When lava is forced up into stratified rock without breaking through, it gives rise to dome-shaped mountains. The intruded lava is said to form a *laccolith.*



From New Physiography, *D. C. Heath & Co.*

Fig. 73.—I, Laccolith. II, Intrusions with Dikes III, Extrusions with Dike. IV, Vent for Ashes, Etc. (Penck)

X. Dikes, Necks, and Sills

A. When erosion has exposed lava which hardened in a fissure, a dike is formed.

Examples.—The dikes of Scotland and Ireland.

B. Lava which has hardened in a volcanic vent may be left by erosion as a conspicuous hill, known as a *volcanic neck.*

Examples.—Devil's Tower in Wyoming; Morro Rock in California.

C. The horizontal sheet of lava left between rock strata after a volcanic intrusion is known as a *sill.*

Example.—The Palisades of the Hudson represent a sill which has been exposed by denudation.

XI. Distribution of Volcanoes.—Volcanic activity is distributed in two great belts and is associated with young and growing mountains.

A. *The Principal Belt.*—The principal belt partly encircles the Pacific Ocean. In this belt are Japan, the Philippine Islands, the South Sea Islands, the

Andes Mountains of western South America, and the Aleutian Islands.

B. *The Second Belt.*—The second belt is a long, broken line forming a secant to the principal belt. It includes the Hawaiian Islands, Mexico, the West Indies, the Mediterranean region, India, and the East Indies.

XII. Vesuvius.—Vesuvius, located on the Bay of Naples, in Italy, is an example of the explosive type of volcano. This volcano lay dormant for centuries, and farms and villages occupied its slopes. In the year 79 it suddenly erupted. The eruption blew off a portion of the cone, and threw up a cloud of dust and steam, forming a great cauliflower cloud. It was accompanied by earthquakes and thunder and lightning. Darkness added to the terror. Pompeii and Herculaneum were buried under volcanic ash and mud, and many thousands of people lost their lives. Vesuvius has had several eruptions since, and in all probability will have others in the future.

XIII. Mauna Loa.—Mauna Loa is an example of the quiet type of volcano. This magnificent mountain rises nearly 14,000 ft. above sea level and about 30,000 ft. above the sea floor, forming the largest volcano in the world. At its top is a great crater more than two miles in diameter. In the depression is a lake of hot lava, partly crusted over; jets of steam rise here and there, and fountains of lava shoot up, sometimes to a height of two or three hundred feet. At times, the lava rises slowly in the crater, and finding or forming fissures in the sides of the mountain, it flows gently down the slopes as rivers of lava.

XIV. Stromboli.—Stromboli, an ever active volcano situated on a small island near Sicily, rises about 3,000 ft. above sea level. Steam rises from crevices in its sides, forming clouds which are lighted up at night by red hot

lava in the crater. Hence its name "the lighthouse of the Mediterranean." There are frequent mild eruptions, during which fragments of hot lava are thrown out from the crater.

XV. Economic Importance of Volcanoes

A. Sometimes destructive to life and property.
B. Help maintain the elevation of land against the destructive agents of erosion which tend to reduce all land to sea level.
C. Have preserved records of past life, as in the case of Pompeii.
D. Have played a part in the formation of valuable mineral deposits, as in western United States. One of the chief sources of sulphur is that deposited by volcanic action on the island of Sicily.

EARTHQUAKES

I. Definition.—An earthquake is a vibration in the bed rock of the Earth.

II. Origin of Earthquakes.—Earthquakes are caused by anything which jars the bed rock, such as an avalanche, the falling in of the roof of a cave, a volcanic explosion, or the faulting and slipping of rock strata, the last being the most important cause.

III. Distribution of Earthquakes.—In general, earthquakes are associated with young and growing mountains, but may occur anywhere. The two principal earthquake belts are the same as the two volcanic belts.

IV. Destructive Earthquakes

A. The *Lisbon earthquake* in 1775 caused a great wave, 60 ft. high, to sweep upon the shore where people had gathered for protection from falling buildings. More than thirty thousand lives were lost.

B. The *Charlestown earthquake* in 1886 destroyed a large part of the city of Charlestown, South Carolina. It was felt as far away as New York and St. Louis.

C. The *San Francisco earthquake* in 1906 caused great destruction of life and property. Fire broke out. The vibrations and slipping of rock strata had broken the water pipes and hence there was no water for fighting the fire. The line of faulting which caused this earthquake was traced along the coast of California for more than two hundred miles.

QUESTIONS

1. Describe two types of volcanoes.
2. Distinguish between *active, dormant,* and *extinct* volcanoes.
3. What are (a) laccoliths; (b) dikes; (c) necks?
4. Describe the two belts of volcanic activity.
5. Describe a volcano of, (a) the quiet type; (b) the explosive type.
6. What is the cause of, (a) volcanoes; (b) earthquakes?
7. Give an account of, (a) the San Francisco earthquake; (b) the Lisbon earthquake.
8. Discuss the economic importance of volcanoes and earthquakes.

CHAPTER XXVIII

SHORE LINES AND HARBORS

I. Migration of Shore Lines.—Shore lines migrate inland or seaward according to whether the land sinks or rises relatively to sea level. If the shore line migrates inland, the coast tends to become more irregular; if it migrates seaward, the coast line tends to become more regular.

II. Evidences of Change of Level.—There are many evidences that portions of sea coasts have risen or have been depressed relatively to sea level. Among these are the following:

A. One portion of the Island of Crete, in the Mediterranean, has risen so that docks which formerly extended into the water are now about 27 ft. above water level. In another portion of this island the land has sunk so that structures built by man are now completely submerged.

B. On the coast of New Jersey, stumps of trees may be seen 10 ft. or more under water at low tide. Old records of colonial days describe titles to lands in this vicinity which are now under water.

C. An old channel of the Hudson River may be traced out to sea across the coastal plain for a distance of more than fifty miles, thus indicating a submergence of the land.

D. The many bays along the Atlantic Coast, including the New York, Delaware, and Chesapeake bays, indicate a lowering of the level of the land and

the consequent entering of the sea into the submerged valleys.

E. On the coast of Scotland are caves developed by wave action which are now 100 ft. or more above the reach of the waves.

F. On the coast of Peru a reef of corals, which could have been built only at sea level, is now about 3,000 ft. above sea level.

III. Classification of Shore Lines.—Shore lines are classified as *regular* and *irregular*.

A. When a coast line migrates *seaward,* either because the land rises or the water recedes, the nearly level ocean floor is exposed and a *regular* shore line is formed.

B. When a coast line migrates *inland,* the sea enters the depressed valleys, forming bays, and an *irregular* coast results.

C. Other factors, such as wave action, glacial action, and shore currents play a part in shaping coast lines.

IV. Elevated Continental Shelves.—When a continental shelf rises so as to move the shore line seaward, a low, flat shore having a straight shore line is formed. Such shores are often swampy and are not suitable for agricultural purposes. Where the soil is sufficiently dry and fertile, the lack of good harbors tends to delay its development. Shores of this type are found in southeastern United States, Yucatan, and Argentina. A slight sinking of these shores in southeastern United States has produced shallow bays, making rather poor harbors.

V. Straight Mountain Coasts.—The uplift of mountains on the edge of a continent produces a straight shore line free from bays, capes, and peninsulas. Consequently there are few harbors. The Pacific coast from Oregon to central Chili

is of this type. There is a break at San Francisco, where a subsidence formed an outlet for the Sacramento Valley, forming at the same time one of the finest harbors in the world. Such a coast cannot be densely inhabited, since the coastal plain is narrow, communication with the interior difficult, and harbors either absent or far apart. It is sometimes called the Pacific coast type.

VI. Embayed Mountainous Coasts.—The encroachment of the sea on a mountainous coast produces a very irregular shore line having many islands and bays and consequently excellent harbors. The northwestern coast of North America and the southwestern coast of South America are of this type.

VII. Ria or Atlantic Coast Type.—Where mountain ranges, instead of being parallel to the coast, meet it at an angle, long narrow bays are formed which resemble fiords. When these bays are deepened by glacial action, *true fiords* are formed. The coasts of Nova Scotia and Maine are of this type.

VIII. Embayed Coastal Plains.—A marked subsidence of a coastal plain permits the sea to enter valleys and form drowned rivers and many bays. The coast of the United States from Maine to South Carolina is of this type. The combined advantages of a wide coastal plain and many harbors cause this region to be highly developed and densely inhabited.

IX. Fiord Coasts.—Many deep, narrow mountain valleys of Norway, deepened by glacial action, meet the sea, forming long narrow bays with steep sides. Such bays are called *fiords.* Alaska, Labrador, Maine, and Norway have fiords. The Hudson Valley may also be considered to be a fiord.

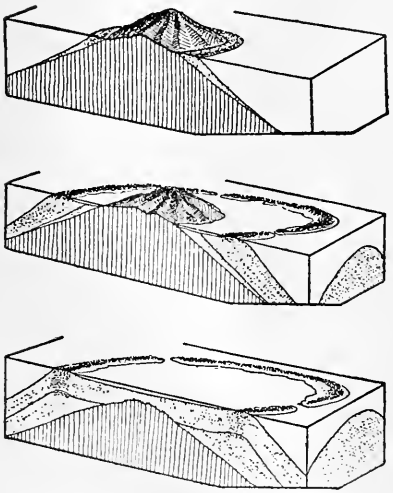
X. Coral.—Coral is a limestone formation built up by a very small animal, called the *coral polyp.* At first the young polyp swims around freely, but soon attaches itself to the bottom and settles down to its life work of building coral reef. There are many varieties of coral, some forming deli-

cately branched, tree-like forms; others, massive dome-shaped masses. Coral thrives in places where

A. The water is 120 ft. or less in depth.
B. The temperature never drops below 68° F.
C. The saltiness is that of normal sea water.
D. The water is in motion, so that food will be brought to the living coral.

XI. Coral Reefs.—Coral develops until it reaches the surface. Wind and waves then break off pieces and build the reef above sea level.

A. *Fringing reefs* are those which are formed close to the land.
B. *Barrier reefs* are those which are formed far enough from the land to enclose a *lagoon* of quiet water.
C. An *atoll* is a ring of coral in the open ocean, enclosing a lagoon. Many atolls have a growth of vegetation, including the cocoanut palm, and are inhabited by man. There is always a break in the ring to allow the tide to flow in and out of the lagoon.



From Davis's Elementary Physical Geography, *Ginn & Co.*

Fig. 74.—Stages in the Development of an Atoll

XII. Formation of Atolls.—Atolls, which are quite common in the tropical Pacific, are built on the peaks of submerged extinct volcanoes that rise from the sea floor. In some cases there seems to have been a volcanic island with a fringing

reef. A slow subsidence permitted the growing coral to maintain the top of the reef at sea level. When the volcanic cone disappeared entirely beneath the water, an atoll was left enclosing a lagoon.

XIII. Formation of Islands and Peninsulas

A. Many islands are formed by the subsidence of land, leaving the higher portions standing above sea level as islands. Many peninsulas are formed in the same manner.

Examples.—The British Isles, Denmark, Labrador, Long Island, Terra del Fuego.

B. Many islands and peninsulas are the result of mountain growth. Alaska, Lower California, the West Indies, Madagascar, New Zealand, the East Indies, the Malay Peninsula, the Philippines, and the Japanese Islands were formed in this manner.

XIV. Harbors.—A harbor is a place where ships may come to anchor and find protection against storms.

A. A *port* is a harbor to and from which ships carry merchandise or passengers.

B. A *port of entry* is a harbor which has a custom house for the legal entry of merchandise.

XV. Classification of Harbors

Type	*Example*
A. River Harbors.	Hamburg, London, New Orleans.
B. Bay Harbors.	San Francisco, Puget Sound, Rio de Janeiro, New York.
C. Island Harbors.	Boston, Bombay, Hong Kong.
D. Lagoon Harbors.	Jamaica Bay, Galveston, Key West.

XVI. Requirements of a Good Harbor

A. A good entrance which is wide and deep enough for large vessels.

B. Freedom from ice in winter and from ice jams at its entrance.

C. Spaciousness and depth of water suitable for anchoring many vessels.

D. Shores that are not too steep, so that good docking facilities may be constructed.

E. A productive country tributary to it, so that there will be a flow of merchandise to and from the harbor. The country which is tributary to a harbor is called its *hinterland.*

XVII. Harbor Improvements

A. Harbor entrances are kept free from sand by dredging, as at New York, or by the construction of jetties, as at New Orleans.

B. Breakwaters are constructed to afford protection from waves, as at Buffalo and Chicago.

C. Floating platforms with movable bridges to docks are constructed where the rise and fall of the tide are excessive, as at Liverpool, England.

D. In many places machinery has been installed for the rapid and economical loading and unloading of ships, such as the grain elevators and ore docks of Buffalo and Cleveland.

QUESTIONS

1. What is the effect of the migration of a shore line, (a) inland; (b) seaward?

2. State four evidences that sea coasts, (a) have risen; (b) have been depressed.

3. Describe, (a) a straight mountainous coast; (b) an embayed mountainous coast; (c) an embayed coastal plain; (d) a fiord coast.

4. Under what conditions does the coral polyp thrive?

5. Describe the formation of, (a) a fringing reef; (b) a barrier reef; (c) an atoll.

6. What are the characteristics of a good harbor?

7. Explain why each of the following is an important seaport: (a) London; (b) Hamburg; (c) Singapore; (d) Galveston; (e) San Francisco; (f) New York.

8. Describe four important harbor improvements.

CHAPTER XXIX

MAP MAKING

I. Spherical Surfaces.—Since the surface of the Earth is spherical, it is impossible to represent it on a flat surface without distortion. Various kinds of projections have been devised to reduce the amount of distortion and to fit maps for the uses to which they are to be put.

II. Map Projection.—A map projection is the framework of parallels and meridians on which the map is drawn.

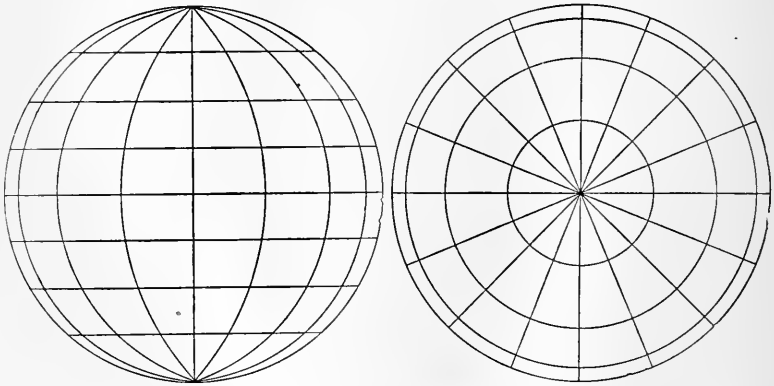


FIG. 75.—ORTHOGRAPHIC PROJECTION

III. Orthographic Projection.—An orthographic projection is a projection made by a distant source of light, such as the Sun, upon a screen placed at right angles to the direction of the rays of light. A map drawn on such a projection has the disadvantage of considerable distortion, which increases from the center toward the margins.

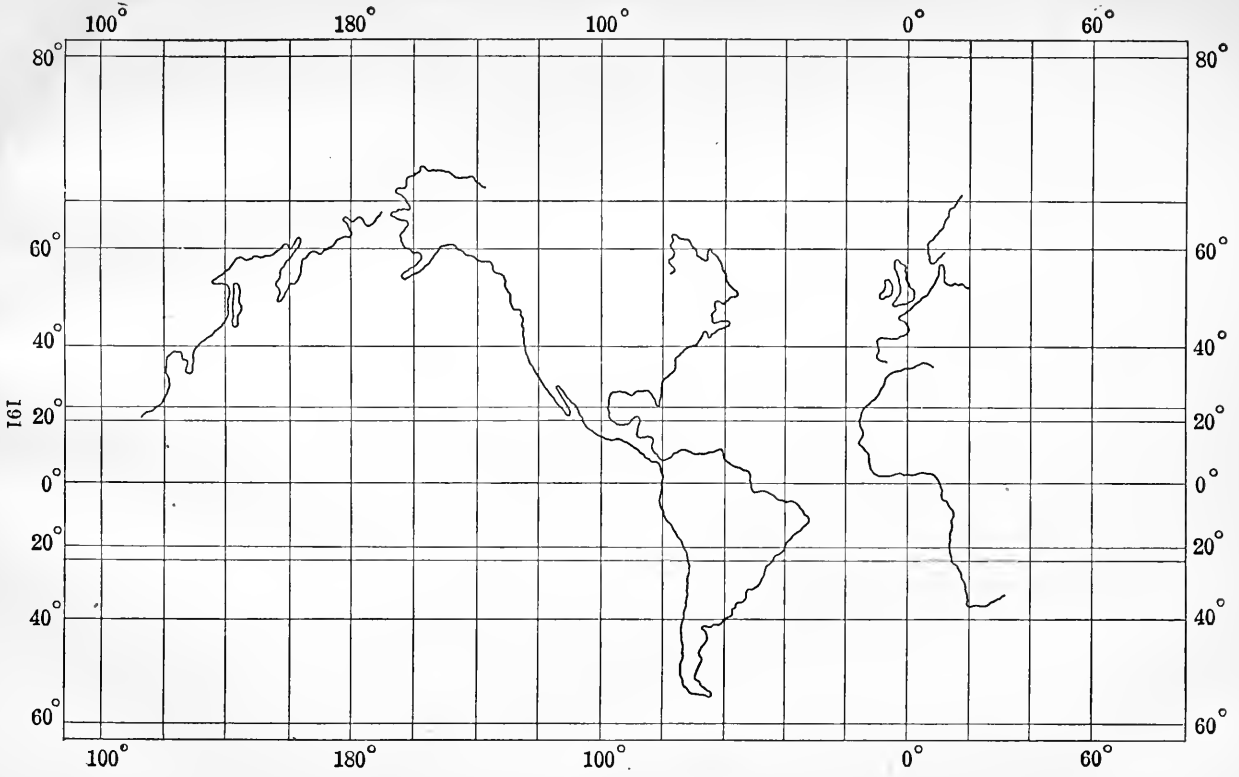


FIG. 77.—MERCATOR'S PROJECTION

IV. Globular Projection.—The globular projection is so planned as to reduce the amount of distortion to a minimum. In this type of projection, parallels and meridians are equally spaced on one another. It is used for drawing maps of hemispheres.

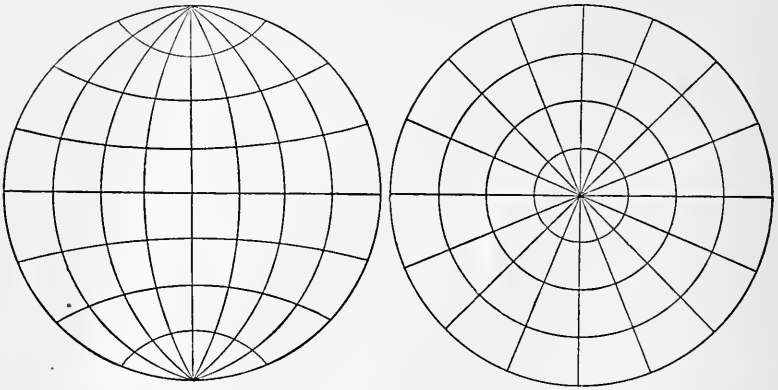


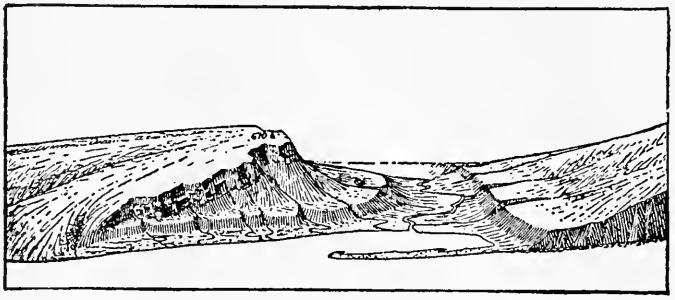
FIG. 76.—GLOBULAR PROJECTION

V. Mercator's Projection.—In a Mercator's projection, the parallels and meridians are represented as straight lines at right angles to one another. The spacing is such that everywhere distances along parallels and meridians from any given point are in the same ratio as on the globe. This type of projection has the disadvantage of great distortion, which increases from the equator toward the poles. It has the advantage of showing directions correctly and of representing the entire surface of the Earth on a single map. It is used for mariners' charts.

VI. Molweide Projection.—In this type of projection, the parallels of latitude are evenly spaced, parallel straight lines. The meridians are ellipses which converge at the poles and are evenly spaced at the equator. A map drawn on this projection is pleasing to the eye and represents the entire surface of the Earth, but has the disadvantage of great dis-

tortion. It is used for indicating the distribution of voleanoes, mineral deposits, etc.

VII. Relief Maps.—Various methods have been devised for showing relief on maps. A relief map which shows elevations and depressions by moulding them in some plastic material gives a very vivid representation, but is not suitable for a printed page. There are four deviees in common use for showing relief on maps.



From PHYSIOGRAPHY FOR HIGH SCHOOLS, *Henry Holt & Co.*

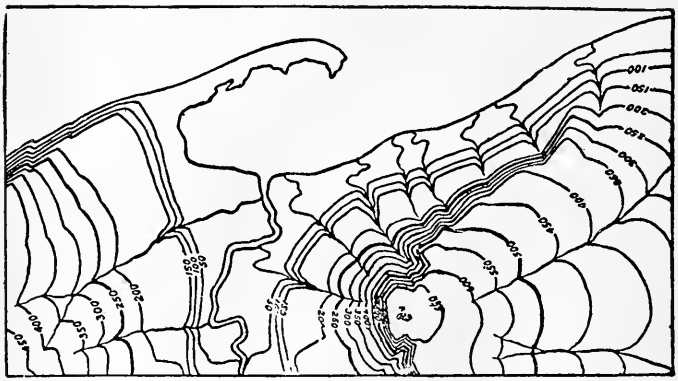
FIG. 78.—A RIVER VALLEY AND ELEVATIONS

A. *Color.*—Relief may be indicated by the use of different colors or by using different shades of one color. It is customary to use the darkest shade for the highest elevation.

B. *Photography.*—A photograph of a relief model gives a very satisfactory representation of relief features.

C. *Hachures.*—Hachures are lines of shading drawn in the direction of steepest slope, or in the direction which running water would take. The lines are close together where the slopes are steep, and far apart where the slopes are gentle. Hachures give very satisfactory results, but are not as accurate as contour lines.

D. *Contour Lines.*—Contour lines are lines drawn on a map through points of equal elevation. Where slopes are steep, the contours are drawn close together; where the slopes are gentle, the contours are drawn far apart. Numbers are printed on contour lines to show the exact elevation. This is the best method for representing relief and is the one used by the United States Geological Survey for making topographical maps.



From PHYSIOGRAPHY FOR HIGH SCHOOLS, *Henry Holt & Co.*

FIG. 79.—THE SAME RIVER VALLEY INDICATED BY MEANS OF CONTOUR LINES

QUESTIONS

1. What is a *projection?*

2. Describe the arrangement of parallels and meridians in, (a) an orthographic projection; (b) a globular projection; (c) a Mercator projection; (d) a Mollweide projection.

3. Discuss the advantages and disadvantages of each of the projections mentioned in question 2.

4. How is relief indicated on maps?

5. Discuss the advantages and disadvantages of the various ways of indicating relief.

APPENDIX

DEFINITIONS

Aeolian mantle rock (or **aeolian soil**).—Rock (or soil) which has been transported and deposited by the wind.

Agonic lines.—Lines on a chart which connect places having no magnetic declination.

Alluvial mantle rock (or **alluvial soil**).—Rock (or soil) which has been transported and deposited by rivers.

Altitude of a celestial body.—The angular distance of the celestial body above the horizon, measured on a great circle.

Anaemometer.—A device for determining the direction and velocity of winds.

Antarctic Circle.—The parallel of latitude which is 66½° south of the Equator. It is determined by the tangential rays of the Sun at the times of the solstices.

Anticline.—An arched upfold of rock strata.

Anticyclone.—A clockwise (in the Northern Hemisphere) movement of air blowing outward from an area of high pressure.

Aphelion.—The position which the Earth occupies when it is farthest from the Sun.

Arctic Circle.—The parallel of latitude which is 66½° north of the Equator. It is determined by the tangential rays of the Sun at the times of the solstices.

Atoll.—A coral island forming a ring which encloses a lagoon.

Aurora borealis.—An electric discharge in the rarefied upper layers of the atmosphere, causing a display of many-colored light. It is seen most frequently on clear, cold nights in the far north.

Axis of rotation.—An imaginary line on which the Earth rotates. Its ends are the North and South Poles.

Barograph.—A device for measuring and recording the pressure of the air.

Barometer.—A device for measuring air pressure.

Beach.—Assorted material left on a shore by wave action or shore currents.

Bore.—The advance of a tidal current as a breaking wave when it enters a V-shaped bay or river mouth.

Butte.—A comparatively small, flat-topped area, having very steep sides, horizontal strata, and a talus at the foot of the cliffs.

Chinook wind.—A wind descending a mountain slope is warmed by compression and is called (in Western United States) a chinook wind. It is often destructive to vegetation.

Chromosphere.—A layer of incandescent gas outside the Sun's photosphere.

Chronometer.—An accurate clock set by Greenwich time.

Cirque.—An amphitheatre-shaped valley-head, formed by the headward corrasion of a glacier.

Civil Day.—The ordinary business and legal day. It begins at midnight, ends at midnight, and is based on mean solar time.

Climate.—The average condition of the atmosphere with respect to its temperature, pressure, winds, and precipitation over a period of time.

Colluvial mantle rock (or **colluvial soil**).—Rock (or soil) which has been transported and deposited by gravity.

Comet.—An astronomical body having an enormous volume and a small mass.

Condensation.—The process of changing a gas or a vapor to the liquid form.

Conduction.—The transfer of heat from a hot body to a cold body by molecular collision.

Constellation.—A group of stars to which a definite name has been given.

Convection.—The transfer of heat by moving masses of a fluid.

Corona.—A halo of light seen around the Sun during a total eclipse.

Corrasion.—The mechanical wearing away of land by abrasion.

Corrosion.—The disintegration of rock by chemical action.

Cusp.—A bar or spit which has formed an angle projecting seaward.

Cyclone.—A counterclockwise (in the Northern Hemisphere) movement of air blowing inward toward a low pressure area.

Declination of a celestial body.—The angular distance of a

celestial body from the sky equator, measured along an hour circle.

Dew point.—The temperature to which a body of air must be cooled to become saturated with water vapor.

Dip.—The angle which a rock stratum makes with a horizontal plane.

Equator.—A great circle at right angles to the Earth's axis of rotation and midway between the poles.

Equinox.—The position of the Earth when the Sun's rays are vertical over the Equator.

Erosion.—The gradual wearing away of the land by weathering and corrasion. It implies also the transportation and deposition of the débris.

Erratic.—A rock fragment differing from the bed rock beneath, which is deposited by a glacier.

Esker.—A ridge of sand and gravel that was deposited in the channel of a subglacial stream.

Evaporation.—The process of changing a substance from the liquid to the gaseous state.

Geyser.—A spring of hot water that erupts more or less regularly.

Glacial mantle rock (or **glacial soil**).—Rock (or soil) which has been transported and deposited by glaciers.

Hail.—A precipitation composed of pellets of ice. The structure of these pellets indicates that they are frozen rain drops, which have been enlarged by successive condensations and freezings upon their surfaces.

Harbor.—A place where ships may come to anchor and find protection against storms.

Heat.—The energy of vibration of the molecules of a body.

Heat Equator.—The line that connects the places on the Earth's surface having the highest temperature.

Hook.—A hook-shaped spit or bar.

Humidity (Absolute).—The actual weight of water vapor in the air, expressed in grains per cubic foot.

Humidity (Relative).—The amount of water vapor which the

air holds compared with what it *could* hold at the given temperature if it were saturated.

Humus.—A dark-brown or black substance produced by the partial decay of vegetable matter in the presence of a limited supply of air.

Hurricane.—A cyclonic storm which originates in the vicinity of the West Indies.

Insolation.—The heat energy received from the Sun by radiation.

Isogonic lines.—Lines on a chart which connect places having the same magnetic declination.

Kame.—An irregularly stratified deposit of sand and gravel formed by a subglacial stream as it emerged from beneath its glacier.

Lacustrine plain.—A plain composed of alluvial soil which settled in the quiet water of a lake.

Latitude.—The latitude of a place is its distance north or south of the Equator, measured in degrees along a meridian.

Light.—A series of waves propagated through the ether which are capable of producing the sensation of sight.

Loam.—A mixture of sand, clay, and humus.

Loess.—Certain large deposits of wind-blown soil.

Longitude.—The longitude of a place is its distance east or west of the prime meridian, measured in degrees along a parallel of latitude.

Magnetic field.—The space surrounding a magnet in which there are magnetic lines of force.

Mantle rock.—Large and small fragments of rock material overlying the bed rock.

Marine plain.—A raised portion of the ocean floor, whose strata remain nearly horizontal.

Mean solar day.—The average length of all the solar days of the year.

Meridian circles.—Great circles passing through the poles and at right angles to the Equator.

Mesa.—A broad, flat-topped area, having very steep sides, horizontal strata, and a talus at the foot of the cliffs.

Meteor.—A bit of rock from outer space which has entered our atmosphere with great speed.

Meteorology.—The scientific study of weather and climate.

Mineral.—An inorganic substance occurring naturally in the Earth's crust. It has a definite chemical composition and definite physical properties.

Monocline.—A titled rock stratum, not a part of a wave form.

Mountain.—A portion of land having a comparatively great elevation and a small summit area.

Neap tide.—The tide of small range caused by the opposition of lunar and solar tides.

Névé.—Granular ice formed by partial melting and re-freezing of snow.

Nunatak.—A mountain peak projecting like an island above a sea of ice.

Parallel of latitude.—A circle on the surface of the Earth parallel to the Equator.

Peak.—A mountain having a single sharp summit.

Penumbra.—The partially lighted portion of a shadow.

Perihelion.—The position which the Earth occupies when it is nearest to the Sun.

Photosphere.—The layer of heavy incandescent vapor surrounding the liquid portion of the Sun. It is the chief source of light for the Earth.

Physiography.—The science which treats of the natural features of the Earth, of the changes which the surface is undergoing, and of the relation between these surface features and life.

Plain.—A broad level area of land, generally lower than adjacent lands, at least on one side.

Planet.—An astronomical body revolving around a sun.

Plateau.—A broad level area of land of higher altitude than adjacent lands or water, at least on one side.

Port.—A harbor to and from which ships carry merchandise or passengers.

Precipitation.—The formation of dew or frost. The falling of rain, snow, hail, or sleet.

Pressure gradient.—The rate of change of atmospheric pres-

sure in any given direction measured in hundredths of an inch in a distance of one latitude degree.

Prime meridian.—The meridian which passes through Greenwich, England.

Psychrometer.—A device for measuring relative and absolute humidity.

Radiation.—The transfer of heat or light by means of ether waves.

Ridge.—A mountain having a long narrow summit.

Rift valley.—A valley which has been formed by the sinking of a block of rock between two nearly parallel fault planes.

Rock.—A mass composed of one or more kinds of minerals.

Salina.—A salt plain left by the drying up of a salt lake.

Satellite.—An astronomical body revolving around a planet.

Saturation point.—The temperature to which a body of air must be cooled to become saturated with water vapor.

Sextant.—An instrument for measuring the altitude of an astronomical body.

Siderial day.—The time it takes for the Earth to make one complete rotation on its axis.

Sleet.—A mixture of hail and rain, or of snow and rain.

Solar day.—The time between two successive crossings of a given meridian by the Sun.

Solstice.—The position of the Earth in its orbit when the vertical rays of the Sun are either farthest north or farthest south of the Equator.

Spit.—A pointed extension of a reef, usually caused by shore currents.

Spring.—Where ground water finds an outlet to the surface in sufficient quantity to cause a stream, a spring is formed.

Spring tide.—The tide of large range caused by the combining of lunar and solar tides.

Stalactite.—An icicle-like limestone formation which hangs down from the roof of a cave.

Stalagmite.—An icicle-like limestone formation which projects upward from the floor of a cave.

Star.—A distant sun which resembles either our own Sun in

being a hot mass of incandescent liquid or gaseous material, or a body which has cooled down from a former incandescent state.

Strike.—The direction taken by a horizontal line drawn on a rock stratum at right angles to its dip.

Syncline.—An arched downfold of rock strata.

Temperature.—The degree or intensity of heat.

Temperature gradient.—The rate of change of temperature in any given direction, measured in Fahrenheit degrees in a distance of one latitude degree.

Thermograph.—A device for measuring and recording temperature.

Thermometer.—A device for measuring the temperature of a body.

Tide.—The periodic rise and fall of the ocean water caused by the gravitative pull of the Moon and Sun.

Till.—The unassorted and unstratified material of a ground moraine.

Tornado.—A cyclonic storm having a small diameter but a great wind velocity.

Tropic of Cancer.—The parallel of latitude which is 23½° north of the Equator, and which marks the position farthest north reached by the vertical rays of the Sun.

Tropic of Capricorn.—The parallel of latitude which is 23½° south of the Equator, and which marks the position farthest south reached by the vertical rays of the Sun.

Tundra.—A frozen plain of the far north which becomes a vast swamp in summer.

Umbra.—The dark portion of a shadow which receives no light from the source that causes the shadow.

Volcano.—A vent in the Earth's crust through which melted rock rises to the surface.

Weather.—The condition of the atmosphere at a given place and time with respect to its cloudiness, humidity, winds, pressure, temperature, and electrical condition.

Zenith distance of a celestial body.—The angular distance of a celestial body from the zenith, measured on a great circle. It is equal to 90° — its altitude.

PHYSICAL GEOGRAPHY

Tuesday, January 23, 1940 — 1.15 to 4.15 p. m., only

Answer all questions in part I, four questions from part II and one question from part III. Answers to the questions in part I should be written on the question paper as directed and handed in with the other answer paper. Whenever questions in part II or in part III so direct, answers to these questions are to be written on the question paper. Answers should be numbered and lettered to correspond with the questions.

Part I

Answer all questions in part I.

Write on the line at the right of *each* statement the *number* preceding the word or expression that makes the statement true. [15]

1. The surface of the moon as seen through a telescope is (1) masked by lunar clouds (2) pitted with craters (3) a network of river valleys 1____

2. Evaporation increases when the air is (1) saturated (2) not moving (3) becoming warmer 2____

3. A national park noted for its existing glaciers is (1) Crater Lake (2) Yosemite (3) Mt. Rainier 3____

4. When the umbra of the moon touches the earth there is (1) a solar (2) a lunar (3) an annular eclipse. 4____

5. The wind belts of the earth (1) always keep the same position (2) shift northward during our spring (3) shift southward during our spring 5____

6. Floods may be prevented by (1) building dams at the headwaters of streams (2) planting trees in the watershed area (3) extensive removal of vegetation from the valley slopes 6____.

7. The sediment load of a stream aids the stream in (1) dissolving the bed rock (2) lowering the bed of the stream (3) weathering the banks of the stream 7____

8. Pervious ground increases the proportion of rain which will (1) become ground water (2) run off (3) evaporate 8____

9. The weather on any day in New York is likely to be the weather of the preceding day in (1) Chicago (2) Boston (3) London 9____

10. More than three fourths of the atmosphere is (1) oxygen (2) nitrogen (3) carbon dioxide 10____

11. Drowned valleys are an indication of (1) uplifted land (2) river capture (3) rising of sea level 11____

12. Young plains are characterized by (1) buttes (2) horizontal rock structure (3) deep residual soil 12____

13. Foucault proved that the earth rotates by an experiment using (1) the shadow of a vertical pillar (2) the altitude of the North Star (3) a pendulum 13____

14. A lunar day is (1) the same length as (2) shorter than (3) longer than a solar day. 14____

15. Shale is composed of consolidated particles of (1) sand (2) clay or mud (3) lime 15____

Write on the line at the right of *each* statement the word or expression which, if inserted in the corresponding blank, will make the statement true. [14]

16. The unassorted material deposited at the ice front of a glacier is called a __(16)__ 16____

17. Calcite is a transparent mineral that has a cleavage in __(17)__ directions. 17____

18. A region of geysers and hot springs indicates recent __(18)__ activity. 18____

19. Water vapor gets into the air by a process called __(19)__ 19____

20. When both thermometers of a hygrometer show the same temperature, the relative humidity is __(20)__ per cent. 20____

21. Many striae were made by __(21)__ which formerly covered North America. 21____

22. Satellites revolve in orbits around __(22)__ 22____

23. Craters are found at the tops of __(23)__ 23____

24. When the altitude of one contour line is 460 feet and that of the next line is 480 feet, the contour interval is __(24)__ feet. 24____

25. The mineral __(25)__, which cleaves readily into thin plates, is used in electrical insulation. 25____

26. An instrument that always shows the time at the prime meridian is called a __(26)__ 26____

27. The slow breaking up of rock by exposure to the atmosphere is called __(27)__ 27____

28. The sun may be seen in the zenith as far north as __(28)__ 28____

29. We receive no light from the moon during the __(29)__ phase of the moon. 29____

Some of the statements below are true and some are false. If the statement is true, write the word *true* on the line at the right; if the statement is false, write the word or expression that must be substituted for the italicized word to make the statement correct. [12]

30. At the time of our winter solstice no sunlight falls on the *South Pole*. 30____

31. Hanging-valley waterfalls are found in *glaciated* areas. 31____

32. An accumulation of angular rocks broken from a cliff is called *talus*. 32_____

33. The *northern* shore of Long Island is an example of an outwash plain. 33_____

34. Swamps are numerous where the water table is *low*. 34_____

35. An observer in New York City sees the noon sun *higher* in the sky on June 21 than on March 21. 35_____

36. To an observer on the North Star the earth would appear to revolve about the sun in a *clockwise* direction. 36_____

37. The climatic effect of Lake Erie is felt strongly over western New York State because of the *trade* winds. 37_____

38. The *Colorado* plateau is an example of a lava plateau. 38_____

39. When the solar tides and lunar tides fall together a tide of *great* range occurs. 39_____

40. Freezing and thawing cause *chemical* weathering. 40_____

41. Where ground water returns to the surface through a natural opening a *well* occurs. 41_____

Write on the line at the right of *each* physiographic feature in column B the *number* of the item in column A that is *especially* noted for that feature. [9]

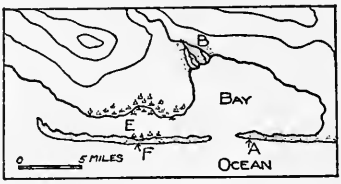
Column A	*Column B*	
42. Continental climate	cyclonic weather changes	
43. Doldrums	daily rainfall all year	
44. Gulf Stream	descending air currents	
45. Horse latitudes	hot summers, cold winters	
46. India	ice-free arctic port	
47. Marine climate	monsoon winds	
48. Murmansk	trade-wind desert	
49. Northern Africa	tundra	
50. Pacific coast	winter rains	
51. Polar climate		
52. Prevailing westerlies		
53. Vladivostock		

Part II

Answer any four questions from part II.

1. *a.* Using at least *four* isobars, draw a diagram of a typical "high" in the United States. Indicate the pressure on *each* isobar. [2]
   b. Place arrows in each quadrant to show the wind direction within the "high." [2]
   c. State the vertical direction of movement of the air at the *center* of the "high." [1]
   d. What change in temperature would you expect as a "high" approaches you home? [1]
   e. Name *two* weather instruments, other than the temperature and pressure instruments, used to obtain information on which weather maps are based. [2]
   f. State the purpose of each instrument named in answer to *e*. [2]

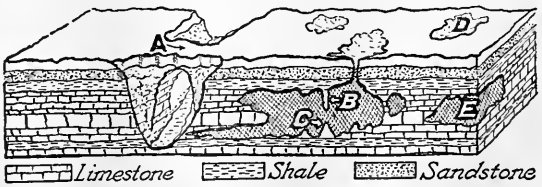
2. The accompanying diagram represents a shore line that has been slightly submerged.



a. What shore feature is represented at A [1]? Explain how this feature was formed [2].
b. What type of feature is located at F [1]? Explain how this feature was formed [2].
c. What type of feature is shown at B? [1]
d. What is the physiographic name for the area at E? [1]
e. Explain why the ocean side of the feature at F is more regular that the landward side. [2]

3. Mars is sometimes called the earth's sister planet.
a. Compare Mars and the earth with respect to *three* of the following: (1) relative size, (2) relative distance from the sun, (3) angle of inclination, (4) period of rotation, (5) period of revolution. [3]
b. Why were astronomers especially interested in Mars last summer? [1]
c. What planet has two recently discovered satellites? [1]
d. Name *two* other planets and state a distinguishing characteristic of each. [4]
e. What is the shape of the orbits of the planets? [1]

4. The accompanying diagram shows physiographic features in a limestone region.
a. Name *three* features that are indicated by capital letters on the diagram. [3]
b. Explain how the features B and D were formed. [4]
c. Name *one* well-known place in the United States where features like B and D are found. [1]
d. Explain how underground drainage like that at the right of the diagram may become a surface stream like that at the left of the diagram. [2]



5. Desert erosion is predominant in large areas of the western part of the United States.

a. Name *two* agents of erosion that change the surface of arid regions. [2]

b. Explain the formation of sand dunes and illustrate with a labeled diagram. [3]

c. Why are occasional cloudbursts especially effective in the sculpturing (erosion) of arid regions? [2]

d. What is the source of the water for through-flowing streams in deserts, such as the Nile and the Colorado rivers? [1]

e. Explain why many lakes in deserts are salt lakes. [2]

6. *a.* What effect does the color of rocks and soils have on the absorption of energy from the sun? [2]

b. Explain how unequal heating of the atmosphere causes winds. [2]

c. Compare the rate of warming of land and water areas of the same latitude. [2]

d. Compare the climate of an island located in mid-ocean with that of a similar island in the same latitude located near a continent. [2]

e. What effect has the rate of warming on the land on the summer temperature of continental interiors? [1]

f. What change in air temperature occurs with increased altitude? [1]

Part III

Answer one question from part III.

7. Time belts were established for our convenience.

a. State the location of the international date line and account for its position. [2]

b. What meridian is halfway around the earth from the international date line? [1]

c. A war bulletin broadcast from London at 1 p. m. was tuned in at Paris, New York and Los Angeles. At what hour at *each* place was the broadcast heard? [3]

d. Memphis, Tenn., 90° W. Long., and El Paso, Texas, 105° W. Long., both use Central Standard Time. At which place does the sun rise first and how much earlier does it rise? [2]

e. The Atlantic Clipper left the airport at Port Washington, N. Y. 8.30 a. m. Thursday. It arrived at the Azores, 30° W. Long., at 6.30 a. m. on Friday. How many hours did it take the plane to make the flight? [2]

8. This is a cross-section diagram of the sort of structure found in parts of New England.

a. What has happened to the rock structure at B? [1]

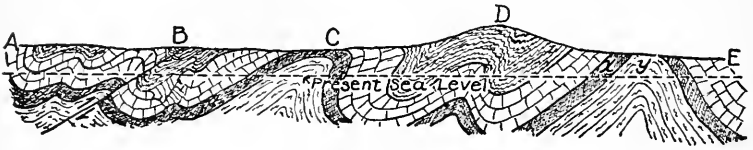
b. Which is older, the rock at *x* or at *y* [1]? Give a reason for your answer [1].

c. What name is given a surface such as that at A-E [1]? How was this surface produced [1]?

d. What erosion feature is represented at D [1]? Give *one* possible reason why it remains higher than the line A-E [1]

e. This region has been uplifted and the streams rejuvenated. On the diagram on the question paper, construct a young stream valley between B and C and indicate, by shading, the rock that the stream must remove to form this valley. [2]

f. How far down can the rocks be worn by the present streams? [1]



PHYSICAL GEOGRAPHY

Tuesday, June 18, 1940 — 1.15 to 4.15 p. m., only

Answer all questions in part I, four questions from part II and one question from part III. Answers to the questions in part I should be written on the question paper as directed and handed in with the other answer paper. Whenever questions in part II or in part III so direct, answers to these questions are to be written on the question paper. Answers should be numbered and lettered to correspond with the questions.

Part I

Answer all questions in part I.

Write on the line at the right of *each* statement the word or expression which, if inserted in the corresponding blank, will make the statement true. [13]

1. At night, latitude may be determined by finding the altitude of .....(1)..... 1._____

2. From a point in the heavens above the North Pole, the earth would appear to rotate in a (an) .....(2)..... direction. 2._____

3. The shape of the orbits of the planets is .....(3)..... 3._____

4. Clouds are formed when moist air is cooled below the .....(4)..... point. 4._____

5. Tree ferns and other forms of extinct life that are preserved in rocks are called .....(5)..... 5._____

6. Bodies that enter our atmosphere from outer space are called .....(6)..... 6._____

7. Solar eclipses can occur only at the .....(7)..... phase of the moon. 7._____

8. The part of a glacier that is near the bedrock moves at a .....(8)..... rate than other parts of the glacier. 8._____

9. The softest mineral in the scale of hardness is .....(9)..... 9._____

10. Steep-sided basins (amphitheaters) found at the upper end of glacial valleys are called .....(10)..... 10._____

11. Ash cones of volcanoes tend to have .....(11)..... slopes. 11._____

12. The climate of continental interiors shows a .....(12)..... temperature range than does that of coastal areas. 12._____

13. Water rising to the surface in arid regions leaves a coating of mineral salts on the surface because the water .....(13)..... 13._____

Write on the line at the right of *each* statement the *number* preceding the word or expression that makes the statement true. [15]

14. The sun is nearest the earth about the time of the (1) vernal equinox (2) autumn equinox (3) summer solstice (4) winter solstice 14._____

15. Cirrus clouds are (1) thunder clouds (2) high, feathery clouds (3) rain clouds (4) low-lying clouds 15____

16. The phases of the moon are caused by (1) the rotation of the earth (2) the revolution of the earth (3) the rotation of the moon (4) the revolution of the moon 16____

17. Many meanders are found in the (1) Hudson River (2) Colorado River (3) Ohio River (4) St. Lawrence River 17____

18. Grindstones are made of (1) sandstone (2) schist (3) granite (4) limestone 18____

19. Bedrock that shows stratification is classed as (1) igneous (2) sedimentary (3) metamorphic (4) unconsolidated 19____

20. The average time interval between two successive high tides is (1) 12 hours, 26 minutes (2) 52 minutes (3) 6 hours, 13 minutes (4) 24 hours, 52 minutes 20____

21. Good evidence of great climatic changes is provided by (1) Weather Bureau records (2) the Dust Bowl (3) coal deposits in polar regions (4) the salt in the seas 21____

22. The horse latitude belts are areas characterized by (1) ascending (2) descending (3) horizontal (4) cyclonic air currents. 22____

23. Oval-shaped hills formed by glacial action are called (1) eskers (2) kames (3) lateral moraines (4) drumlins 23____

24. Whenever dew is forming, the relative humidity of the air is (1) 100% (2) 75% (3) 50% (4) 10% 24____

25. A mountain region that has been worn nearly to base level is (1) Tennessee (2) southern New England (3) the Pacific coast (4) the Dakotas 25____

26. Offshore bars tend to (1) remain in position (2) be moved seaward (3) remain below sea level (4) be moved landward 26____

27. Anticlines and synclines are characteristics of (1) faulted (2) folded (3) volcanic (4) domed mountains. 27____

28. The water in artesian wells comes from (1) sinkholes (2) a distant collecting area (3) local rainfall (4) clay beds 28____

In *some* of the following statements the term in italics makes the statement incorrect. For each *incorrect* statement, write on the line at the right the term that must be substituted for the italicized term to make the statement correct. For each *correct* statement, write the word *true* on the line at the right. [13]

29. Great Salt Lake is the remnant of the former fresh-water *Lake Bonneville.* 29____

30. Tides of great range, caused by the combined effect of sun and moon, are called *spring* tides. 30____

31. The elevation above which perpetual snow is found on mountains is called the *divide.* 31____

32. Oxbow lakes are formed during the *old-age* stage of rivers. 32____

Part III

Answer one question from part III.

7. *a.* What is a fault? [1]

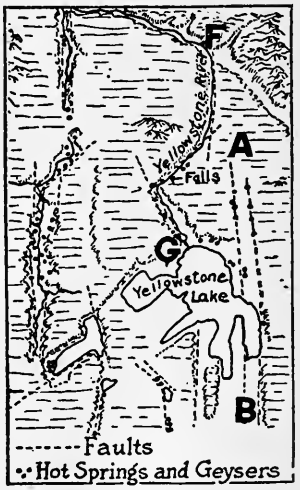
b. Explain the action of a geyser. [2]

c. Account for the position of the hot springs between A and B. [2]

d. Why does the Yellowstone River follow the course indicated from G to F, with its abrupt turns, rather than some other course? [2]

e. Why would you expect the Yellowstone River to maintain a uniform volume? [1]

f. The Yellowstone Falls are famous. Explain how waterfalls are formed. [2]



8. During the past winter a number of physiographic factors—extremely low temperatures, short duration of daylight, numerous lakes and swamps—were of military advantage to Finland.

a. Give *two* reasons for the very low winter temperatures. [2]

b. Account for the presence of the many lakes and swamps. [2]

c. Why is Petsamo, in the northern part of Finland, ice-free throughout the year? [2]

d. On December 21, what is the lowest latitude that has 24 hours of darkness? [1]

e. On December 21, in northern Finland, maximum duration of daylight is three hours. What is the maximum duration of daylight there on June 21? [1]

f. Name *two* planetary wind belts that affect the Finnish climate. [2]

EARTH SCIENCE

(Physical Geography)

Tuesday, January 21, 1941 — 1.15 to 4.15 p. m., only

Answer all questions in part I, four questions from part II and one question from part III. Answers to the questions in part I should be written on the question paper as directed and handed in with the other answer paper. Whenever questions in part II or in part III so direct, answers to these questions are to be written on the question paper. Answers should be numbered and lettered to correspond with the questions.

Part I

Answer all questions in part I.

Write on the line at the right of *each* statement the *number* preceding the word or expression that best completes the statement. [16]

1. An instrument used to identify elements in the sun's envelop is the (1) psychrometer (2) sextant (3) seismograph (4) spectroscope 1____

2. The United States topographic maps that show relief by lines connecting all points of equal elevation above sea level are called (1) hachure maps (2) shaded maps (3) contour maps (4) relief maps 2____

3. A region that has hot summers and cold winters with little rainfall is situated (1) on the coast (2) on the windward side of mountains (3) in a continental interior (4) in mid-ocean 3____

4. The earliest known forms of life lived (1) on land (2) in ocean deeps (3) on the continental shelf (4) in the air 4____

5. The southern part of Long Island is (1) a moraine (2) a till sheet (3) an outwash plain (4) a peneplain 5____

6. Tributary streams frequently are lengthened by (1) gradation (2) lateral corrasion (3) headward erosion (4) retreat of waterfalls 6____

7. The calendar which we use was put into effect by (1) Julius Caesar (2) Galileo (3) Pope Gregory (4) Newton 7____

8. The trade winds blow from (1) warm to cool regions (2) west to east (3) cool to warm regions (4) low to high pressure regions 8____

9. The horse latitudes are areas of (1) descending (2) ascending (3) horizontal (4) longitudinal air currents. 9____

10. Icebergs come from (1) ice packs (2) floe ice (3) glacier fronts (4) névé 10____

11. Valley glaciers exist in the United States in (1) Mount Rainier National Park (2) the southern Rockies (3) the White Mountains (4) the Basin Ranges 11____

Part II

Answer four questions from part II.

1. *a.* Explain *one* way in which clouds may form. [2]
   b. Name *two* types of clouds. [2]
   c. What type of pressure area is usually accompanied by clouds? [1]
   d. Why are cloudless skies usual in the horse-latitude belt? [2]
   e. Name *two* forms of condensation that occur at or near the earth's surface. [2]
   f. Account for the formation of *one* of the forms of condensation named in answer to *e*. [1]

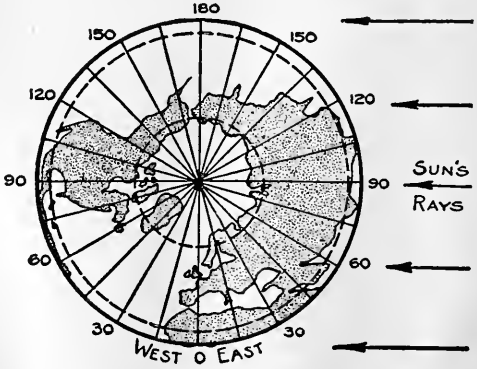
2. Each item in the list below characterizes a river or river valley during one of the stages—Youth, Maturity, Old Age—of the erosion cycle. Write these headings on your answer paper and under *each* heading write the characteristics most closely associated with that stage of the cycle. [10]

Characteristics

broad flood plains	development of meanders	V-shaped gorges
steep gradients	many swamps and lakes	lateral erosion
natural levees	stream grades near base level	waterfalls
	rapid headward erosion	

3. The accompanying diagram is a view of the earth as seen from above the North Pole at the time of the autumnal equinox.

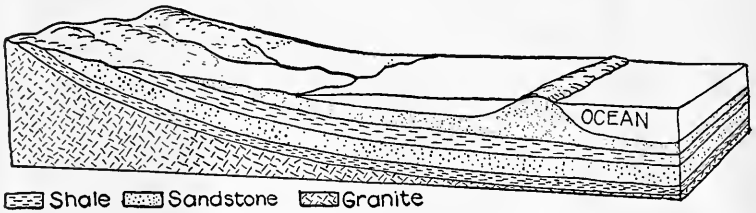
   a. Indicate with an arrow the direction of the earth's rotation [1]
   b. What date does the diagram represent? [1]
   c. Shade on the diagram the part of the earth that is in darkness. [1]
   d. Along what meridian is it (1) noon, (2) sunrise? [2]
   e. What time is it in the Central standard time belt? [1]
   f. Indicate with slanting lines that part of the earth that will be in darkness two hours later. [1]



g. Where are the sun's rays vertical on this date? [1]
h. How many hours of daylight are there at the equator on this date? [1]
i. On what other date are conditions similar on the earth? [1]

4. Glacial deposits are widespread over the northern United States.
a. What type of glacial deposit marks the boundary of the glaciated area in the United States? [1]
b. Name *two* large rivers that follow, in general, the boundary of the glaciated area. [2]
c. In what way was the United States benefited by glacial deposits? [1]
d. Distinguish between Alpine glaciers and continental glaciers. [2]
e. Explain the meaning of each of *four* of the following terms: esker, crevasse, névé, striae, cirque, drumlin. [4]

5. The accompanying diagram shows a coastal region in which artesian wells might be located.



a. Label on the diagram the aquifer and impervious layers that are necessary for an artesian well. [2]
b. Indicate by arrows and label the catchment (collecting area). [1]
c. Draw on the diagram artesian wells in *two* different areas. [2]
d. How does an artesian well differ from an ordinary well? [1]
e. Why is the water of artesian wells usually purer than ordinary well water? [2]
f. Explain why artesian wells do not contain local ground water. [1]
g. Explain why New England is un unfavorable area for artesian wells. [1]

6. a. Describe the climatic changes indicated by *four* of the following: [4]
(1) Great Salt Lake
(2) Coal deposits in polar regions
(3) Salt and gypsum deposits in New York State
(4) Fossil coral reefs in Greenland
(5) Scratched and polished bedrock in the British Isles
b. Name *four* factors that influence the climate of a region. [2]
c. Compare (1) the climate of the British Isles with that of Labrador, (2) the climate of Nebraska with that of Long Island; show how climatic factors determine these differences in climate. [4]

Part III

Answer one question from part III.

7. *a.* What is an isotherm? [1]

b. State *two* factors that cause isotherms to bend toward the pole or equator. [2]

c. Climatic zones are sometimes bounded by parallels of latitude. Tell why such boundaries are poor and give a better method of bounding climatic zones. [2]

d. How do you account for snow-capped areas in places which receive the sun's vertical rays? [1]

e. Account for the small annual precipitation in Arctic regions. [2]

f. Describe simple experiments that show how the temperature and the exposed surface area of a liquid affect the rate of evaporation of the liquid. [2]

8. The accompanying diagram represents a cross section through California and western Arizona.

a. On the diagram label (1) an alluvial plain, (2) a plateau, (3) a mountain. [3]

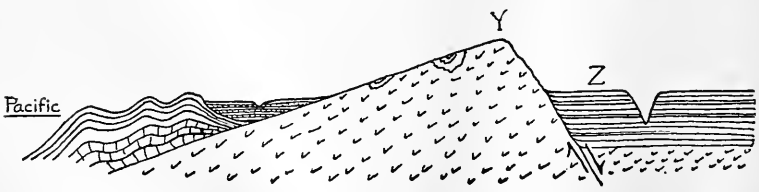
b. Explain the origin of the feature at Y. [2]

c. What class of rock is found at Z? [1]

d. How may one determine the relative age of rocks such as those at Z? [1]

e. (1) Which are older, the rocks at Y or the rocks at Z? [1]
(2) What is shown on the diagram to indicate their relative age? [1]

f. Name a plateau region of the eastern United States. [1]



EARTH SCIENCE

Tuesday, June 17, 1941 — 1.15 to 4.15 p. m., only

Answer all questions in part I, four questions from part II and one question from part III. Answers to the questions in part I should be written on the question paper as directed and handed in with the other answer paper. Whenever questions in part II or in part III so direct, answers to these questions are to be written on the question paper. Answers should be numbered and lettered to correspond with the questions.

Part I

Answer all questions in part I.

Write on the line at the right of *each* statement the term which, if inserted in the corresponding blank, will make the statement true. [15]

1. The earth loses less energy (heat) by ....(1).... when clouds are overhead. 1.....

2. Winds spiral toward the center of a ....(2).... pressure area. 2.....

3. The density of the atmosphere at sea level is determined by the pressure and the ....(3)....of the air. 3.....

4. The temperature at which air becomes saturated with water vapor is called the ....(4).... 4.....

5. Stratified rocks are usually deposited in ....(5).... 5.....

6. Water evaporates rapidly when the relative humidity of the surrounding air is ....(6).... 6.....

7. When large masses of the earth's crust slip along fault planes, ...(7).... occur. 7.....

8. The density of dry air is ....(8).... than that of moist air when measured under similar conditions of temperature and pressure. 8.....

9. The free end of a bar built out from the mainland is called a (an) ....(9).... 9.....

10. Striated and polished bedrock surfaces are formed by ....(10).... 10.....

11. Cyclones and anticyclones, in the United States, usually move in a (an) ....(11).... direction. 11.....

12. The light reflected from the dark portion of the moon at its new crescent phase is called ....(12).... 12.....

13. Glacial troughs formed by erosion of ice below sea level are called ....(13).... 13.....

14. A mineralogist uses a steel knife blade to test the ....(14).... of a mineral. 14.....

15. Large-scale air movements (winds) that reverse direction with the changing seasons are called ....(15).... 15.....

Write on the line at the right of *each* statement the *number* preceding the term that makes the statement true. [19]

16. The earth is about two million miles nearer the sun in our (1)summer (2)spring (3)fall (4)winter 16_____

17. Lakes in a river's course will ultimately (1)increase in size (2)grow deeper (3)be filled by deposition (4)remain unchanged 17_____

18. A continental glacier now exists in (1)Labrador (2)Siberia (3)Greenland (4)Australia 18_____

19. Circular star trails show that the (1)stars are rotating (2)earth is revolving (3)earth is rotating (4)stars are revolving 19_____

20. The great coal deposits found in the Pennsylvania region indicate that the climate of this region was once (1)arctic (2)subtropical (3)temperate (4)subarctic 20_____

21. At the equator the daily period of insolation is (1) less than 12 hours (2)12 hours (3)14 hours (4)18 hours 21_____

22. Horizontal layers of sedimentary rock are found in (1)block mountains (2)complex mountains (3)synclines (4)plateaus 22_____

23. On a contour map lines that are close together indicate that the land (1)is level (2)slopes gently (3)slopes steeply (4)is swampy 23_____

24. Slate was formed by (1)heat and pressure (2) deposition under water (3)cooling of lava (4)accumulation of organic remains 24_____

25. Wind is less active in eroding humid than arid regions because the (1)wind velocity is less there (2)particles of mantle rock are too large (3)vegetation holds the soil (4)bedrock is resistant 25_____

26. We can not see the moon at the (1)old crescent phase (2)first quarter phase (3)new moon phase (4)new gibbous phase 26_____

27. Waterfalls are due to (1)a series of weak rock layers (2)a series of limestone layers (3)resistant rock over weak rock (4)a shale rock layer overlying resistant rock 27_____

28. A sea cave at an altitude of 100 feet above sea level would indicate (1)recent severe storms along the coast (2)great tidal range (3)uplift of the land (4)land submergence 28_____

29. The Atlantic coastal plain from New Jersey to the Rio Grande is the result of (1)submergence (2)glaciation (3) emergence (4)faulting 29_____

30. The energy of a young stream is used chiefly to (1)widen its valley (2)deepen its valley (3)widen its flood plain (4)deposit sediment 30_____

31. In New York State rain usually occurs in the (1) northwestern (2) northern (3) southwestern (4) southeastern part of a low-pressure area. 31.....

32. A slow-moving stream carries (1) only dissolved mineral salts (2) boulders (3) no sediment (4) fine silt 32.....

33. The final product of the decay of naturally radioactive elements is (1) calcium (2) iron (3) lead (4) uranium 33.....

34. The relative age of rocks in widely separated areas is shown by (1) index fossils (2) intrusions (3) mineral content (4) rock texture 34.....

In *some* of the following statements the term in italics makes the statement incorrect. For each *incorrect* statement, write on the line at the right the term that must be substituted for the italicized term to make the statement correct. For each *correct* statement, write the word *true* on the line at the right. [16]

35. If the inclination of the earth's axis were 35 degrees, the summers in the Northern Hemisphere would be *colder.* 35.....

36. Differences in *atmospheric pressure* cause winds. 36.....

37. In swampy regions the water table is *high.* 37.....

38. Astronomers have seen *only one side* of the rotating moon. 38.....

39. Most sand bars in a meandering river occur near the *outside* of the curve. 39.....

40. A macadam highway will heat *less* quickly in summer than will a stream beside it. 40.....

41. Comets that move in closed orbits are members of the *solar system.* 41.....

42. *Continental* glaciers always move from higher to lower elevations. 42.....

43. The tides have *greater* range when the moon is in first or last quarter. 43.....

44. Continental climate has a *small* temperature range. 44.....

45. The Rocky Mountains are classed as *fault* mountains. 45.....

46. The most accurate estimates of the age of the earth are based on changes that occur in *radioactive* minerals. 46.....

47. Resistant rock masses that have not been worn down at the end of an erosion cycle are called *monadnocks.* 47.....

48. Mauna Loa has an (a) *ash* cone. 48.....

49. Frost forms more readily on cold, *cloudy* nights. 49.....

50. On a clear summer day the atmospheric pressure over a land area *is greater than* that over a near-by sea area. 50.....

Part II

Answer four questions from part II.

1. *a.* Describe briefly and illustrate the *two* types of change that occur during the formation of mantle rock from bedrock. [4]
   b. Name *two* factors that affect the rate at which mantle rock is formed. [2]
   c. Explain why residual mantle rock is more common in the southern part of the United States than in the northern part. [1]
   d. Explain how *one* of the following kinds of mantle rock is formed: alluvial soil, beach sand, desert sand, moraine. [1]
   e. Name *two* methods by which soil erosion is controlled. [2]
2. *a.* Make a labeled diagram that shows the *prevailing westerly,* the *trade-wind* and the *calm* belts at the time of the equinox. The diagram should include both Northern and Southern hemispheres. [4]
   b. Why do the wind belts shift northward during our spring? [1]
   c. Name the calm belt characterized by daily, heavy rains and account for these rains. [2]
   d. In what wind belt does the wind blow steadily from the same direction for weeks at a time? [1]
   e. Name the wind belt in which you live. [1]
   f. Why does the wind in New York State not blow continuously from the same direction? [1]
3. Account for each of *five* of the following: [10]
   a. There are many rocky islands off the coast of Maine.
   b. More rain falls on the western slope of the northern Rockies than on the eastern slope.
   c. Scientists believe that a lofty mountain range once existed in the Piedmont area of Virginia and North Carolina.
   d. Layers of shale are not found between layers of slate.
   e. Volcanic peaks frequently occur in belts or chains rather than as single scattered peaks.

f. Barometric readings are used to forecast both fair and stormy weather.

g. Many sinkholes occur in Florida.

4. *a.* The diagrams represent fossils named in this list: brachiopod, crinoid, dinosaur, tree fern, trilobite. Under each of *three* of these diagrams write the name of the fossil shown. [3]

   b. Of the fossils shown, name *one* that lived in swamps and *two* that lived in ocean waters. [3]

   c. Describe *two* ways in which evidence of former life has been preserved. [2]

   d. Explain how fossils indicate past changes in the relation of land and sea. [2]

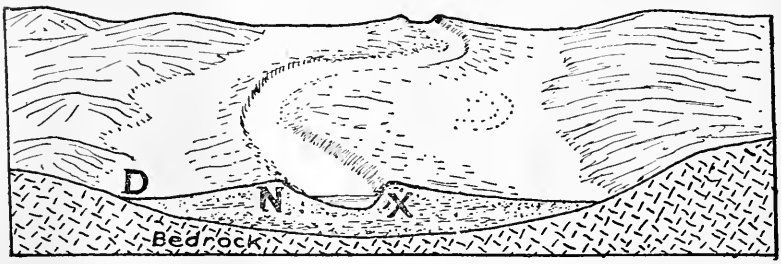
5. *a.* Name the star nearest to our solar system and give its approximate distance in miles from the earth. [A "light year" is about 6,000,000,000,000 miles.] [2]

   b. State two similarities between our sun and other stars. [2]

   c. The color of light emitted by a star is an indication of its surface temperature. What are the relative temperatures of yellow, white and red stars? [3]

   d. How is the composition of our sun and other stars determined? [2]

   e. To what galaxy does our solar system belong? [1]



6. *a.* On the diagram, indicate with an arrow the swiftest current between N and X. [1]

   b. Explain why the river bank at X is steeper than that at N. [2]

   c. What evidence shows that the river has a graded profile (profile of equilibrium)? [1]

   d. Account for the curved course of the river. [2]

   e. In what stage of the erosion cycle is this river? [1]

   f. Where on this diagram are swamps likely to exist? [1]

g. State the characteristics of the soil and mantle rock beside the river. [1]

h. Account for the slope of the surface from N to D. [1]

Part III

Answer one question from part III.

7. *a.* Name *three* types of rock structure formed during mountain uplift and draw a diagram that illustrates *one* of these types. [4]

   b. Where is a mountain uplift now occurring and what evidence indicates this process? [2]

   c. Account for the recent earthquakes in the mature-mountain region of central New England. [1]

   d. Discuss the theory of isostasy as it applies to mountain building. [3]

8. *a.* Describe an experiment to determine whether soil or water is the better absorber of radiant energy. [2]

   b. Describe an experiment to determine the dew point of the air. [2]

   c. Why do airplane pilots need to know the dew point? [1]

   d. An aneroid barometer reads 28.05 inches at the foot of Mt. Whiteface and 25.03 inches at the observation tower on the summit.

   (1) Find the height of the mountain. [1]

   (2) Find the elevation above sea level of the summit of Mt. Whiteface, assuming that the barometric pressure at sea level is 29.90 inches. [1]

   e. Describe simple experiments that show the effect of the following on the rate of evaporation of water: (1) exposed surface area, (2) motion of surrounding air, (3) temperature. [3]

EARTH SCIENCE

Tuesday, January 20, 1942—1.15 to 4.15 p. m., only

Answer all questions in part I, four questions from part II and one question from part III. Answers to the questions in part I should be written on the question paper as directed and handed in with the other answer paper. Whenever questions in part II or in part III so direct, answers to these questions are to be written on the question paper. Answers should be numbered and lettered to correspond with the questions.

Part I

Answer all questions in part I.

Write on the line at the right of *each* statement the *number* preceding the term that best completes the statement. [18]

1. The planet that closely resembles the Earth is (1) Mars (2) Saturn (3) Uranus (4) Neptune 1_____

2. Dew forms at night most rapidly when (1) the air is dry (2) a strong wind is blowing (3) the air is warm and quiet (4) still warm air cools rapidly 2_____

3. Ground water moves most easily through (1) shale (2) sandstone (3) quartzite (4) slate 3_____

4. The Hawaiian Islands were formed (1) by faulting of the ocean bed (2) by uplift of the ocean bed (3) by coral animals (4) by volcanic action 4_____

5. On the Antarctic continent the North Star is (1) never seen (2) seen in the north (3) seen on the horizon (4) seen in the zenith 5_____

6. Offshore bars are formed chiefly by (1) wind (2) coral growth (3) waves (4) tides 6_____

7. The intrusive igneous rocks that make up the Palisades of the Hudson form a (1) dike (2) sill (3) laccolith (4) batholith 7_____

8. Our winter occurs when (1) the earth is farthest from the sun (2) the twilight circle touches the poles (3) the earth's axis is tipped more than 23½° (4) the north pole points away from the sun 8_____

9. The theory of isostasy attempts to explain the origin of (1) continents (2) the solar system (3) anticyclones (4) the ice age 9_____

10. Heat is distributed through the lower air mainly by the process of (1) reflection (2) insolation (3) conduction (4) convection 10_____

11. When shale weathers it crumbles to (1) sand (2) clay (3) gravel (4) marl 11_____

12. The mineral in granite least affected by the weathering agents of a humid climate is (1) feldspar (2) biotite (3) hornblende (4) quartz 12_____

13. Few surface streams but many sinks and lakes are found in Florida because the underlying rock is (1) sandstone (2) shale (3) limestone (4) conglomerate 13_____

14. As a plateau region develops from youth to maturity, its surface becomes (1) higher (2) less eroded (3) more irregular (4) eroded to base level 14_____

15. The kind of rock that forms the Catskills is (1) intrusive igneous (2) metamorphic (3) sedimentary (4) extrusive igneous 15_____

16. Naturally cemented beds of gravel form the rock called (1) shale (2) sandstone (3) conglomerate (4) quartzite 16_____

17. A continental icecap may be found in (1) the Swiss Alps (2) Glacier National Park (3) Greenland (4) Alaska 17_____

18. The last great ice age occurred during the (1) Triassic (2) Devonian (3) Cambrian (4) Pleistocene period. 18_____

Write on the line at the right of *each* statement the term which, if inserted in the corresponding blank, will make the statement true. [12]

19. The temperature of the air falls during the night because the earth then loses heat by __(19)__ 19_____

20. The rate of movement of a glacier is __(20)__ in the center than at the sides. 20_____

21. The name of the rock found floating on water after volcanic eruptions is __(21)__ 21_____

22. The small bodies that move in orbits between Mars and Jupiter are called __(22)__ 22_____

23. New York State is located in the wind belt called __(23)__ 23_____

24. The principal volcanic belt of the world encircles the __(24)__ 24_____

25. The interior of the United States has a (an) __(25)__ type of climate. 25_____

26. If the amount of water vapor present in a given volume of air remains constant, the relative humidity of the air will __(26)__ when the temperature of the air increases. 26_____

27. The eastern side of mountain ranges in the __(27)__ wind belt is the rainy side. 27_____

28. Trade winds that blow across great land areas cause a (an) __(28)__ climate. 28_____

29. The planetary wind belts shift with the change in position of the __(29)__ 29_____

30. The __(30)__ monsoons bring rain to northern India. 30_____

In *some* of the following statements the term in italics makes the statement incorrect. For each *incorrect* statement, write on the line at the right the term that must be substituted for the italicized term to make the statement correct. For each *correct* statement, write the word *true* on the line at the right. [20]

31. The rising and setting of the moon is due to the earth's *revolution.* 31_____

32. The steepest side of a sand dune is the *windward* side. 32_____

33. Different constellations are visible during the year because of the *revolution* of the earth. 33_____

34. The position of the earth's axis in December is *parallel* to the position of the earth's axis in June. 34_____

35. When molten rock cools rapidly on the earth's surface, the crystals so formed are *large.* 35_____

36. The Adirondack Mountains have been a land mass since the close of the *Archeozoic* Era. 36_____

37. Some comets move about the sun in *closed* orbits. 37_____

38. The dry season in Southern California occurs when the *Horse Latitude Belt* is over that area. 38_____

39. *Mature* rivers build flood plains. 39_____

40. In *dry* weather the water table rises. 40_____

41. The coastal plain of Florida is known to be *a submerged* coast. 41_____

42. The older Appalachians (Blue Ridge) are *complexly folded* mountains. 42_____

43. The day that begins and ends at the international date line is called the *civil* day. 43_____

44. Young rivers carrying sediment erode *less* rapidly than do similar rivers carrying no sediment. 44_____

45. The smaller the angle of insolation the *greater* the radiant energy received on each unit of the earth's surface. 45_____

46. Steep volcanic cones are built of *lava flows.* 46_____

47. Vertebrates first appeared during the *Proterozoic* Era. 47_____

48. *Rainy* weather usually follows the passage of a low-pressure area. 48_____

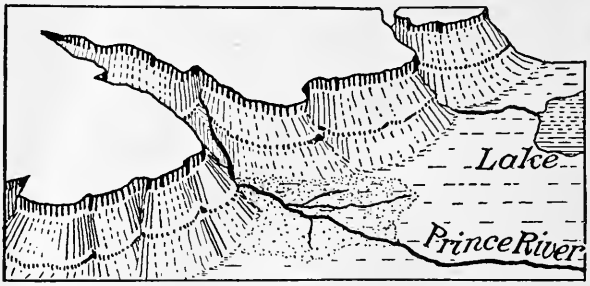
49. Rock fragments that make river water look muddy are in *solution.* 49_____

50. In summer, during the daytime, the air temperature over land areas is *lower than* that over adjacent water areas. 50_____

Part II

Answer four questions from part II.

1. *a.* On the diagram label the following: (1) a canyon, (2) an alluvial fan, (3) a place where headward erosion is occurring, (4) a talus slope, (5) an extensive resistant rock layer, (6) a distributary. [6]
   b. Explain the formation of an alluvial fan. [2]
   c. How does a delta differ from an alluvial fan? [1]
   d. Explain why the cliff retreats at places where there are no streams. [1]



2. Relatively level land areas are formed in a variety of ways. Explain the formation of *five* of these areas: (*a*) northern Egypt near the Nile, (*b*) eastern Texas, (*c*) southern Long Island, (*d*) Arizona near the Grand Canyon, (*e*) North Dakota near the Red River of the North, (*f*) northern Siberia, (*g*) central California (the Great Valley). [10]

3. The history of our earth has been very long.
   a. Describe a method that has been used to estimate the age of the earth. [2]
   b. Name *two* eras in earth history [2]. State *one* important event for which *each* is noted [2].
   c. Name *two* forms of ancient life found as fossils in rocks. [2]
   d. Describe *two* ways by which fossils are formed. [2]

4. *a.* Make a labeled diagram that shows the sun and the *four* principal phases of the moon as seen from the earth. [4]
   b. Why is the range of spring tides greater than the range of neap tides? [2]
   c. Why does the moon rise some 50 minutes later each succeeding night? [2]
   d. Distinguish between a solar and a lunar eclipse. [2]

5. Explain each of *five* of the following: [10]
   a. The trade winds become hooked trades when they cross the geographic equator.
   b. The yearly range of temperature in the temperate zones is greater than that at the equator.
   c. Great natural amphitheaters are found at the heads of valleys in the northern Rockies.

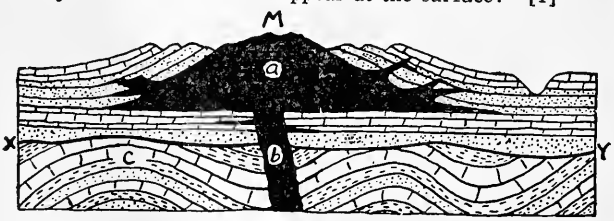
d. The coldest part of the Northern Hemisphere is in Siberia and not at the North Pole.
e. The great mountain chains of the earth are located along continental coasts.
f. Unusually brilliant auroral displays occur at certain times.

6. Many nations no longer broadcast weather data.
   a. Explain why United States weather forecasters need Canadian weather data. [2]
   b. Name *three* weather conditions usually associated with high-pressure areas. [3]
   c. Why did Germany expect to benefit by establishing weather stations in Greenland? [1]
   d. Describe the path of hurricanes that reach the United States and account for it. [2]
   e. Describe *two* characteristics of a hurricane that distinguish it from an ordinary low-pressure area. [2]

Part III

Answer one question from part III.

7. These questions refer to the accompanying diagram.
   a. Name the geologic structures indicated by the letter *a, b* and *c.* [3]
   b. Name the type of mountain shown and explain its formation. [2]
   c. Label the youngest rock shown and give a reason for your choice. [2]
   d. Indicate, by shading, a place where contact metamorphism may have occurred. [1]
   e. What does the unconformity $x - y$ show about the history of this region? [1]
   f. Why does the rock at *M* appear at the surface? [1]



8. *a.* Distinguish solar time from standard time. [2]
   b. State the approximate location and the purpose of the international date line. [2]
   c. When it is noon at 90° E. longitude, at what longitude is it midnight? [1]
   d. A transport plane leaves New York at 9 a. m., Friday and arrives at San Francisco, 120° W. longitude, at 1.30 a. m., Saturday. How many hours does the trip require? [2]
   e. A news broadcast was heard in New York State on Tuesday at 7.30 p. m., E. S. T. Reports were given from Ankara, 30° E. longitude, London, 0° longitude, and Singapore, 105° E. longitude. What was the hour and day in *each* place? [3]

EARTH SCIENCE

Tuesday, June 16, 1942 — 1.15 to 4.15 p. m., only

Answer all questions in part I, four questions from part II and one question from part III. Answers to the questions in part I should be written on the question paper as directed and handed in with the other answer paper. Whenever questions in part II or in part III so direct, answers to these questions are to be written on the question paper. Answers should be numbered and lettered to correspond with the questions.

Part I

Answer all questions in part I.

Write on the line at the right of *each* statement the *number* preceding the word or expression that best completes the statement. [20]

1. A dark-colored, fine-grained igneous rock is (1) basalt (2) granite (3) pumice (4) obsidian 1_____

2. When the moon passes through the earth's umbra, there is (1) a lunar eclipse (2) a solar eclipse (3) a partial eclipse (4) no eclipse 2_____

3. The length of time since the last glacial period (Pleistocene) is estimated as (1) 1,000,000 (2) 75,000 (3) 55,000 (4) 25,000 years. 3_____

4. Cyclonic areas usually cross the United States in (1) two (2) five (3) nine (4) eleven days. 4_____

5. Wind is the chief agent of erosion in the state of (1) Washington (2) Arizona (3) Tennessee (4) Vermont 5_____

6. Betelgeuze gives off a (1) yellow (2) blue (3) white (4) red light. 6_____

7. The vertical rays of the sun during a six-month period move over a total of (1) 23½° (2) 47° (3) 66⅓° (4) 90° on the earth's surface. 7_____

8. The time of great coal formation was during the (1) Azoic (2) Proterozoic (3) Paleozoic (4) Cenozoic era. 8_____

9. Meanders occur when a river has (1) few tributaries (2) a graded profile (3) waterfalls (4) a deep canyon 9_____

10. The Mesozoic era is known as the age of (1) mammals (2) vertebrates (3) trilobites (4) reptiles 10_____

11. The ocean floor is more regular than the land surface because there is more (1) erosion (2) weathering (3) deposition (4) faulting 11_____

12. The gas that constitutes about .03 per cent of the atmosphere is (1) nitrogen (2) argon (3) oxygen (4) carbon dioxide 12_____

13. Great continental ice sheets are now found in (1) Alaska (2) northern Siberia (3) Labrador (4) Antarctica 13_____

14. A mature river usually has (1) many falls and rapids (2) natural levees (3) broad flood plains (4) many tributaries 14_____

15. Proof that the sun rotates is obtained by observing (1) solar prominences (2) meteors (3) solar eclipses (4) sunspots 15_____

16. An instrument used to determine latitude is the (1) altimeter (2) hygrometer (3) chronometer (4) sextant 16_____

17. San Francisco Bay was formed by (1) glacier action (2) submergence (3) emergence (4) volcanic action 17_____

18. The scientist who formulated the law of wind deflection is (1) Agassiz (2) Le Conte (3) Ferrel (4) Chamberlin 18_____

19. The red coloring in many rocks is due to the presence of (1) quartz (2) gypsum (3) hematite (4) talc 19_____

20. A rock composed of cemented mud is (1) sandstone (2) marble (3) shale (4) gneiss 20_____

In *some* of the following statements the term in italics makes the statement incorrect. For each *incorrect* statement write on the line at the right the term that must be substituted for the italicized term to make the statement correct. For each *correct* statement, write the word *true* on the line at the right. [15]

21. The temperature at which air becomes saturated with water vapor is called the *absolute humidity.* 21_____

22. An example of a ground-water deposit is *travertine.* 22_____

23. When the thermometer readings on a hygrometer show a great difference, the relative humidity is *low.* 23_____

24. Tides in the open ocean have a *greater* range than tides along the coast. 24_____

25. In the *troposphere* temperature drops uniformly with increased altitude. 25_____

26. The prevailing northwesterlies are located *north* of the equator. 26_____

27. Residual mantle rock may be formed by *frost action.* 27_____

28. A drumlin is the result of *river* action. 28_____

29. Heat energy is released when water vapor *condenses.* 29_____

30. The proportion of oxygen in the earth's crust is *greater* than that of oxygen in the atmosphere. 30_____

31. Tributary streams become lengthened by *lateral* erosion. 31_____

32. The direction of the movement of the Labrador ice sheet may be determined by *moraines.* 32_____

33. The most distant objects in the heavens are the *nebulae.* 33_____

34. The direction of the air currents at the doldrum belt is *downward.* 34_____

35. Water masses heat and cool more slowly than earth masses because *water* has a greater heat capacity. 35_____

Write on the line at the right of *each* statement the word or expression which, if inserted in the corresponding blank, will make the statement true. [15]

36. Deposits called —(36)— are formed when the velocity of streams is suddenly checked. 36._____

37. Isotherms are more regular in the —(37)— Hemisphere. 37._____

38. Mantle rock from Canada was transported to the United States by —(38)— 38._____

39. Water has a lower temperature in the —(39)— season than land at the same latitude. 39._____

40. Fossil corals show that the climate of a region was once a —(40)— climate. 40._____

41. A macadam highway will heat —(41)— quickly in summer than a stream next to it. 41._____

42. The distance of 6 trillion miles traveled by a light ray is called a —(42)— 42._____

43. In a (an) —(43)— well the water rises above the local water table. 43._____

44. Cyclones and anticyclones are thought to originate along the margin between the polar easterlies and the —(44)— wind belts. 44._____

45. The difference in elevation indicated by two adjacent contour lines is called the —(45)— 45._____

46. The basins of the Great Lakes resulted from erosion by —(46)— 46._____

47. Winds in the Northern Hemisphere blow to the right of the pressure gradient because of the earth's —(47)— 47._____

48. The radiant energy that reaches the earth from the sun is called —(48)— 48._____

49. A volume of air contains 2 grams of water vapor. If that volume of air can hold 4 grams of water vapor at that temperature, the relative humidity of the air is —(49)— %. 49._____

50. The date at which the sun sets at the North Pole is —(50)— 50._____

Part II

Answer four questions from part II.

1. Explain the meaning of each term in *five* of the following pairs: (*a*) alluvial fan — delta, (*b*) fossil — index fossil, (*c*) isobar — isotherm, (*d*) lateral moraine — ground moraine, (*e*) sill — dike, (*f*) weather — climate. [10]

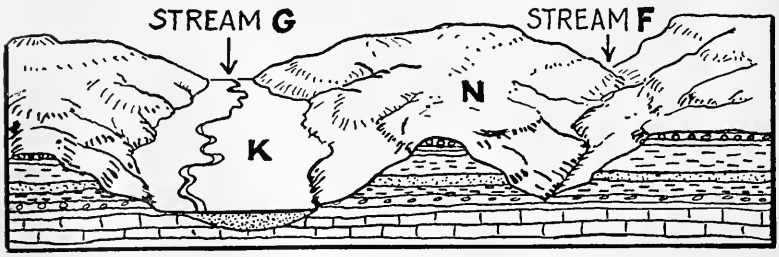
2. *a.* What causes *each* of the following: (1) high wind velocity, (2) cumulus clouds, (3) lower relative humidity at noon than at 9 a. m. of the same day? [6]

b. A cyclone approaches a weather station from the west. State the resulting change in *each* of the following: (1) thermograph, (2)) weather vane, (3) barograph, (4) sunshine recorder. [4]

3. Carbon dioxide dissolves in ground water to form weak carbonic acid; this acid dissolves some rocks.
   a. Name a source of the carbon dioxide in ground water. [1]
   b. Name *two* rocks readily dissolved by ground water that contains carbon dioxide. [2]
   c. Name *two* features that result from erosion by ground water and explain how *one* of the features named was formed. [3]
   d. Name *two* features that result from deposition from ground water and explain how *one* was formed. [3]
   e. Explain how ground water may help the formation of bedrock. [1]

4. *a.* The lowest recorded temperature occurred at Verkhoyansk, in northeastern Siberia. The highest recorded temperature occurred on the Libyan desert of northern Africa. Account for the extreme temperatures at these places. [4]
   b. Account for the even temperature and the abundant rainfall of the island of Hawaii. [2]
   c. Explain why the annual rainfall is
      (1) High in the northwestern part of the United States. [2]
      (2) Low in southern Arizona. [2]

5. Vulcanism was once active in the United States.
   a. Explain how vulcanism was responsible for each of *three* of the following: (1) the Palisades of the Hudson, (2) the Columbia Plateau, (3) Crater Lake, Oregon, (4) the Black Hills. [6]
   b. Name *two* rock-forming minerals commonly found in igneous rock. [2]
   c. Distinguish between the conditions of formation of a granite and those of a basalt. [2]



6. *a.* On the diagram indicate a divide, using a dashed line. [1]
   b. In what stage of development is (1) stream *F*, (2) stream *G*? [2]
   c. State *two* evidences that indicate the stage of development of stream *G*. [2]
   d. Explain the chief process by which stream *F* is changing its valley. [1]
   e. Does the rock structure indicate that this region is a plateau or a mountain? Explain. [2]

f. Name a section of the eastern United States that shows features similar to those on the diagram. [1]

g. Compare the type of soil at *K* with the soil at *N*. [1]

Part III

Answer one question from part III.

7. Evidences of widespread crustal uplift and erosion are associated with the geologic eras of the earth's history.

a. Name the era with which each of *three* of the following mountain systems is associated: (1) Appalachians, (2) Sierra Nevadas, (3) Adirondacks, (4) Rockies. [3]

b. Classify according to structure each of *two* of the mountains mentioned in *a*. [2]

c. How is a peneplane formed? Draw a cross-section diagram that shows a peneplane. Name a region that illustrates a peneplane. [3]

d. What is meant by the erosion cycle of a land mass? [2]

8. For *each* of the following places fill in the table by writing the name of the *wind* or *calm* belt that prevails there at the season indicated: [10]

Place	January (Winter)	July (Summer)
New York State (43° North Latitude)		
Southern California (35° North Latitude)		
Northern India (20° North Latitude)		
New Zealand (40° South Latitude)		
Panama Canal Zone (8° North Latitude)		

EARTH SCIENCE

Tuesday, January 19, 1943 — 1.15 to 4.15 p. m., only

Answer all questions in part I, four questions from part II and one question from part III. Answers to the questions in part I should be written on the question paper as directed and handed in with the other answer paper. Whenever questions in part II or in part III so direct, answers to these questions are to be written on the question paper. Answers should be numbered and lettered to correspond with the questions.

Part I

Answer all questions in part I.

Write on the line at the right of *each* statement the *number* preceding the term that best completes the statement. [16]

1. Air masses that move from Canada toward the United States are usually (1) cool and dry (2) cool and moist (3) warm and dry (4) warm and moist 1_____

2. The chief work of a river in old age is (1) deposition of sediment (2) downward erosion (3) headward erosion (4) sideward erosion 2_____

3. The length of a lunar month is (1) 15 (2) 24 (3) 27⅓ (4) 29½ days. 3_____

4. A shore line of submergence is characterized by (1) many lagoons (2) poor harbors (3) promontories (4) shallow water 4_____

5. A mountain region in youth is characterized by (1) mesas (2) monadnocks (3) rounded peaks (4) sharp peaks 5_____

6. Pacific War Time corresponds to the standard time at the (1) 75th (2) 90th (3) 105th (4) 120th meridian west longitude. 6_____

7. The shortest route between the United States and Russia is (1) across the Atlantic Ocean (2) a great circle route (3) along a meridian (4) along a parallel of latitude 7_____

8. A rock that is weathered rapidly by frost action is (1) impervious (2) pervious (3) soft (4) soluble 8_____

9. Sedimentary bedrock in contact with (1) clay (2) fossils (3) magma (4) peat is metamorphosed. 9_____

10. Rain is brought to the interior of continents by (1) passing anticyclones (2) migration of the Horse Latitudes (3) descending air (4) passing cyclones 10_____

11. The striae in the northeastern states are traces of glacial movement from a center in (1) Greenland (2) Labrador (3) the Arctic (4) the Great Lakes 11_____

12. The course of a river with a flood plain is (1) meandering (2) steep (3) straight (4) ungraded 12_____

13. Plateaus usually have (1) anticlines (2) flat-topped divides (3) low relief (4) many swamps 13_____

14. A boulder rolled around on a stream bed will aid in forming a (1)cavern (2)kettle hole (3)pothole (4)sinkhole 14_____

15. We see one half of the lighted portion of the moon at the (1)first quarter (2)new crescent (3)new gibbous (4)new moon phase. 15_____

16. The most extensive plains region of the world is located in (1)central India (2)Australia (3)northern Siberia (4)the Amazon basin 16_____

Write on the line at the right of *each* statement the term which, when inserted in the blank, will make the statement true. [19]

17. A planet that resembles the Earth in its rotation period is ____ 17_____

18. The retreat of a waterfall indicates that the process of ____ is occurring. 18_____

19. Frost forms when the ____ is below 32° F. 19_____

20. A deposit called a ____ is built where a swift stream flows into a lake. 20_____

21. The earth rotates eastward 30° in ____ hours. 21_____

22-23. In the northern hemisphere, winds in a "high" tend to be deflected to the ____ of the pressure gradient. 22_____ This deflection is caused by the earth's ____ 23_____

24. The crumbling of a rock due to temperature changes is called weathering. 24_____

25. All parts of the earth have 12 hours of daylight on ____ 25_____

26. The zero contour line on a map represents ____ 26_____

27. The last part of a volcano to be removed by erosion is the ____ 27_____

28. An example of a plateau formed by fissure lava flows is the ____ 28_____

29. The roof of a limestone cave may collapse and leave a ____ 29_____

30. Ground water that contains ____ dissolves limestone. 30_____

31. Islands in the South Pacific have a (an) ____ type of climate. 31_____

32. A planet that goes through phases similar to our moon is ____ 32_____

33. The leeward sides of high mountain ranges have a ____ rainfall. 33_____

34. Earthquakes occur when rocks slip along a ____ 34_____

35. A meandering stream deposits sediment on the ____ of the curve. 35_____

In *some* of the following statements the term in italics makes the statement incorrect. For each *incorrect* statement, write on the line at the right the term that must be substituted for the italicized term to make the state-

ment correct. For each *correct* statement, write the word *true* on the line at the right. [15]

36. The monsoons that blow over southeastern Asia during January are the *northeast* monsoons. 36_____

37. Ground fog (radiation fog) occurs chiefly during the *day*. 37_____

38. Our moon belongs to the class of bodies known as *planetoids*. 38_____

39. The length of the *rotation* period of the earth determines the length of its years. 39_____

40. Low relative humidity *increases* the rate of evaporation of water. 40_____

41. If the center of a cyclone is directly south of a place, the winds at that place will be from the *south*. 41_____

42. The density of the air *decreases* as the altitude increases. 42_____

43. Winds become hooked trades when they cross the *Tropic of Cancer*. 43_____

44. Airplanes that fly *north* of the center of a "low" from San Francisco to Hawaii are aided by the air movement around the "low." 44_____

45. Winters in mid-continent are *less severe* than on the coast. 45_____

46. When it is noon, Tuesday, in Los Angeles, it is *Tuesday* in Australia. 46_____

47. When a wet-bulb and a dry-bulb thermometer are exposed to air completely saturated with water vapor, they indicate the *same* temperature. 47_____

48. Drowned valleys are formed when sea level *drops*. 48_____

49. When numerous lakes exist in the upper course of a river, they tend to *increase* flood conditions near the river mouth. 49_____

50. A good absorber of insolation is also a good *reflector* of insolation. 50_____

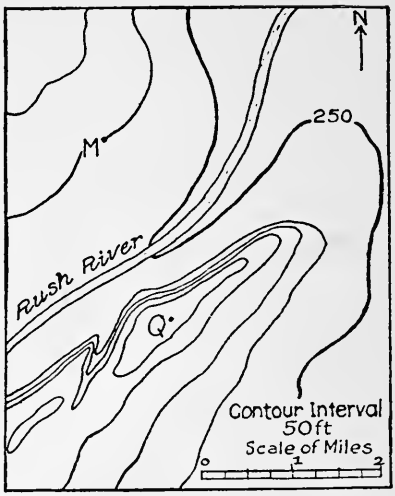
Part II

Answer four questions from part II.

1. Each of the following items is the result of constructive or destructive action by an agent of erosion or by weathering: (1) alluvial fans, (2) canyons, (3) cirques, (4) drumlins, (5) dunes, (6) flood plains, (7) hanging valleys, (8) moraines, (9) residual soils, (10) sandblasted rocks. Place the *number* of *each* item in its proper position in the table. [10]

	Wind	*Rivers*	*Glaciers*	*Weathering*
Constructive action				
Destructive action				

2. *a.* State the altitude at point *M*. [1]
   b. State the direction of flow of the Rush River and explain how the direction of flow of a river may be determined from a contour map. [2]
   c. What is the greatest altitude at point *Q*? [1]
   d. What is the distance from *M* to *Q*, to the *nearest quarter of a mile?* [1]
   e. Label, on the diagram, a steep slope and a gentle slope. [2]
   f. Label a tributary valley west of point *Q*. Draw the stream that flows through this valley. In what stage of the erosion cycle is this valley? [3]



3. *a.* Explain the heating of the earth's atmosphere. [2]
   b. Why does the warmest part of the day usually occur three hours after noon? [2]
   c. Name *two* factors *of* the atmosphere that affect the amount of solar energy reaching the earth's surface and state the effect of each factor named. [2]
   d. The polar regions receive insolation continuously during six months. Why are these regions not the warmest places on the earth? [2]
   e. Compare and explain the rate of warming of land and water areas at the same latitude. [2]

4. Weather observations are made every four hours at hundreds of meteorological stations in the United States.
   a. Name *four* weather elements shown on weather maps and mention the instrument used to measure each weather element named. [4]
   b. Lightning is not especially harmful to aircraft. Explain why thunderstorms are serious hazards to aircraft. [2]
   c. Name a type of cloud that indicates (1) rising air, (2) air in horizontal motion. [2]
   d. Why do airplane pilots need to know the dew point of the air along their flight path? [2]

5. Minerals are increasingly important to the war effort.
   a. Name *two* of the common chemical elements that form minerals. [2]

b. Name *four* common rock-forming minerals. [4]
c. Name a rock in which each of *two* of the minerals named is usually found. [2]
d. State an economic use for each of *two* of the minerals named. [2]

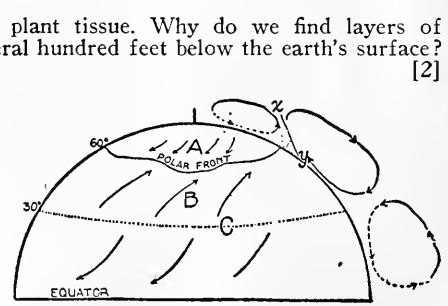
6. *a.* Why do star groups appear to swing in a circle during the night? [2]
b. What star is at the approximate center of the circle? How is this star used to determine the latitude of a ship? If the ship is at 50° north latitude, how far above the horizon will this star be? [3]
c. What is the longitude of a ship when the ship's time is two hours earlier than Greenwich time? [1]
d. Why do we see different groups of stars in the summer and in the winter sky? [2]
e. Name *two* heavenly bodies that are not stars but that, like stars, may appear in constellations. [2]

Part III

Answer one question from part III.

7. The anthracite fields of Pennsylvania lie in a folded mountain region, whereas the bituminous fields are in plateau area.
a. The coal is found in synclines. Draw a labeled diagram that illustrates coal in a syncline. [2]
b. Geologists think that the coal deposits were once more extensive than they now are. Draw dotted lines on the diagram to show where the coal once was. What became of the missing coal? [2]
c. Explain how mountain folds are formed. [2]
d. The bituminous coal in the plateau and the anthracite in the mountains started to form during the same geologic period. Explain the process by which bituminous coal was changed to anthracite. [2]
e. The coal came from plant tissue. Why do we find layers of bituminous coal several hundred feet below the earth's surface? [2]

8. *a.* Name the wind belt at *A* and at *B*. [2]
b. Name the belt at *C* and tell whether this region is characterized by high or by low air pressure. [2]
c. In what region, shown on the diagram, do cyclones develop, and what is their general direction of movement? [2]



d. A vertical section of air is shown at the right of the diagram. Is the cooler air mass above or below the boundary $x - y$? Is the more moist air mass above or below the boundary? [2]
e. Explain why rainfall occurs, as shown, below the boundary $x - y$. [2]

EARTH SCIENCE

Tuesday, June 15, 1943 — 1.15 to 4.15 p. m., only

Answer all questions in part I, four questions from part II and one question from part III. Answers to the questions in part I should be written on the question paper as directed and handed in with the other answer paper. Whenever questions in part II or in part III so direct, answers to these questions are to be written on the question paper. Answers should be numbered and lettered to correspond with the questions.

Part I

Answer all questions in part I.

Write on the line at the right of *each* statement the *number* preceding the term that best completes the statement. [15]

1. The coarse-grained igneous rock that always contains quartz and feldspar is (1) granite (2) pumice (3) obsidian (4) basalt 1_____

2. The sun's vertical rays strike the earth's surface farthest south on (1) June 21 (2) September 23 (3) December 21 (4) March 21 2_____

3. Sun spots show that the (1) earth rotates on its axis (2) sun rotates on its axis (3) earth revolves about the sun (4) sun is moving through space 3_____

4. An intrusion of igneous rock that cuts across sedimentary layers is called a (1) dike (2) sill (3) laccolith (4) boss 4_____

5. The thin feathery clouds that fly at high levels above the earth's surface are known as (1) stratus (2) altocumulus (3) cirrus (4) cumulus 5_____

6. The chief mineral found in limestone and marble is (1) quartz (2) mica (3) calcite (4) feldspar 6_____

7. The weather instrument that gives a continuous record of atmospheric pressure is the (1) barograph (2) mercurial barometer (3) thermograph (4) anemometer 7_____

8. When the moon casts its umbra on a portion of the earth's surface, the eclipse there is (1) total solar (2) total lunar (3) partial solar (4) partial lunar 8_____

9. The air mass that brings hot and humid weather to the southern and eastern parts of the United States during the summer is the (1) Continental Polar (2) Maritime Tropical (3) Maritime Polar (4) Superior 9_____

10. The (1) Arctic circle (2) equator (3) 45th parallel (4) Tropic of Cancer is a great circle 10_____

11. Most earthquakes occur in regions of (1) extensive glaciation (2) bad lands (3) young mountains (4) maturely dissected plateaus 11_____

12. On June 21 at the Arctic circle there will be (1) 0 (2) 12 (3) 18 (4) 24 hours of daylight. 12_____

13. Weather Bureau maps show atmospheric pressures in (1) inches (2) millimeters (3) millibars (4) pounds per square inch 13.....

14. The fact that sea caves are sometimes found a considerable distance inland is evidence that the shore line has (1) emerged (2) submerged (3) been modified by the growth of corals (4) been altered by the action of ground water 14.....

15. Rising currents of air are (1) warmed by expansion (2) warmed by compression (3) cooled by expansion (4) cooled by compression 15.....

Write on the line at the right of *each* statement the term which, when inserted in the blank, will make the statement true. [20]

16. Ground water that contains dissolved ..... is an effective erosion agent in limestone areas. 16.....

17. The name of a light spongy volcanic rock is ..... 17.....

18. Elevations that separate adjacent river basins are called ..... 18.....

19. The scalar fraction 1/62,500 found on many contour maps means that one inch on the map represents a distance of approximately ..... 19.....

20. Breaks in bedrock along which displacements occur are called ..... 20.....

21. As the result of strains set up by the uneven rate of movement of glaciers, ... develop in the ice. 21.....

22. The portion of the atmosphere characterized by decreasing temperatures as altitude increases is known as the ..... 22.....

23. The energy absorbed by land during the day is lost at night by ..... 23.....

24. A river that cuts sideward rather than downward is in the ..... stage of its erosion cycle. 24.....

25. The belt of high-pressure calms located about 30° north of the equator is the ..... 25.....

26. The earth is nearest the sun in our ..... season. 26.....

27. At noon on shipboard, a chronometer reads 4 p. m. Greenwich time. The longitude of the ship is ..... 27.....

28. The extremely cold Russian winters are typical of the ..... type of climate. 28.....

29. The winds that blow equatorward from the horse latitudes are the ..... 29.....

30. Compressed layers of ..... become shale. 30.....

31. Rock fragments that accumulate at the foot of cliffs because of the action of gravity are known as ..... 31.....

32. No place has a longitude of more than ..... degrees. 32.....

33. Land masses heat more ..... than do water masses exposed to the same amount of insolation. 33.....

34. The coral rings that inclose lagoons in the South Pacific are called ..... 34.....

35. The light reflected from the dark portion of the moon at its new crescent phase is called ..... 35.....

In *some* of the following statements the term in italics makes the statement incorrect. For each *incorrect* statement, write on the line at the right the term that must be substituted for the italicized term to make the statement correct. For each *correct* statement, write the word *true* on the line at the right. [15]

36. Isobars that are far apart indicate *low* wind velocities. 36._____
37. Rounded pebbles are produced by *glacial* action. 37._____
38. A river usually carries the largest portion of its rock load in *solution.* 38._____
39. *Igneous* rock is formed when sedimentary rock is altered by heat and pressure. 39._____
40. The galaxy of stars in which our sun is located is *Andromeda.* 40._____
41. Winds are deflected to the right of the pressure gradient in the Northern Hemisphere as a result of the earth's *revolution.* 41._____
42. The irregular coast line of Maine is an example of a shore line of *submergence.* 42._____
43. *Transported* mantle rock resembles the bedrock beneath it. 43._____
44. The lunar eclipse that was visible in New York State last February occurred during the *full* moon phase. 44._____
45. When it is noon, Wednesday, on Guadalcanal, (approximately 160° E. longitude) it is *Tuesday* in the United States. 45._____
46. Igneous rocks that have formed by the *slow* cooling of magma have small crystals. 46._____
47. The seasonal winds that bring heavy rainfall to India blow from the *northeast.* 47._____
48. If the earth's axis were inclined more than 23½°, the winters in the Northern Hemisphere would be *warmer.* 48._____
49. The percentage of oxygen in the earth's crust *is greater than* that in the earth's atmosphere. 49._____
50. If an anticyclone is directly north of a place, the winds at that place will blow from a *westerly* direction. 50._____

Part II

Answer four questions from part II.

1. Weathering agents cause surface rocks to disintegrate.
   a. Distinguish between mechanical and chemical weathering and give an example of *each* type. [4]
   b. How does weathering assist erosion? [2]
   c. Name *two* factors that control the rate at which weathering occurs. [2]
   d. Explain why granite weathers more rapidly than marble in arid (dry) regions. [2]

2. A knowledge of the positions of stars and the movements of other heavenly bodies is important to navigators.
   a. Name a star used by the navigator to determine latitude in the Northern Hemisphere and describe the observation that he makes. [2]

b. Planets may be mistaken for stars. State *two* ways by which planets can be distinguished from stars. [2]

c. At times, the heavenly bodies can not be seen and radio equipment can not be used. Describe briefly a method that a navigator can use to determine his position. [2]

d. Explain why navigational stars appear to change their positions during the night. [2]

e. The stars Antares, Arcturus, Betelgeuze, Sirius and Vega are used by navigators. Name the constellation in which each of *two* of these stars is located. [2]

3. Write physiographic explanations of *five* of the following: [10]

a. Airplane pilots try to avoid flying through cumulonimbus clouds (thunderheads).

b. Rain occurs almost every day on the Solomon Islands.

c. The weather in the stratosphere is safer for flying than is that of lower altitudes.

d. The falls at Niagara have retreated several miles from their former position.

e. Volcanos frequently occur along fairly straight lines.

f. Dry weather occurs during June along the north coast of Africa.

4. Wells supply some 70% of the drinking water used in the United States.

a. Distinguish between the wet-weather and the dry-weather water tables. [2]

b. Make a fully labeled diagram that shows the conditions necessary for the formation of an artesian well. [4]

c. Explain why the water in artesian wells is free from local contamination. [2]

d. Explain why the water from flowing artesian wells comes out under its own pressure. [2]

5. *a.* Explain fully how to determine the relative humidity of the air. [4]

b. What effect does relative humidity have on the rate of evaporation of water? [2]

c. State *two* factors that cause condensation of water vapor from the air. [2]

d. Fogs occur frequently in the Aleutian Islands. Explain how fogs are formed. [2]

6. Mountains are formed by folding, faulting or doming of the earth's crust or by combinations (complex mountains) of these processes.

a. Name and identify mountain ranges formed by each of *three* of the above processes. [3]

b. Make labeled diagrams that show the *structure* of *two* types of mountains. [2]

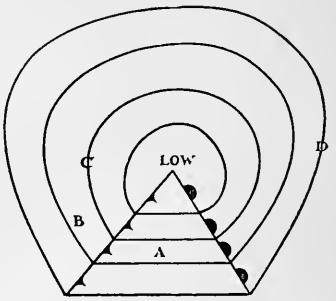
c. Explain why mesas and buttes are characteristic features of old plateaus. [2]

d. Name a region that is a peneplane, and describe the formation of peneplanes. [3]

Part III

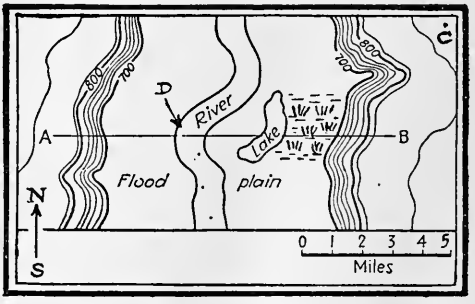
Answer one question from part III.

7. The diagram represents a well-developed cyclonic area (low) moving from west to east across the United States.



a. Label, on the diagram, the warm and the cold fronts. [2]
b. Draw arrows on the diagram that represent the circulation of winds within this area. [2]
c. Explain why the atmospheric pressure is lower at *C* than at *D*. [1]
d. Explain why the air temperature is lower at *B* than at *A*. [2]
e. Where, in the cyclonic area, does the greatest wind shift occur? [1]
f. Explain why precipitation usually occurs along the fronts. [2]

8. The diagram shows a section of a large river and its flood plain.



a. State the contour interval used. [1]
b. What is the elevation of the flood plain? [1]
c. State the elevation of the bluffs above the flood plain. [1]
d. What is the width of the flood plain along the line *A-B*? [1]
e. What is the *greatest possible* elevation above sea level of point *C*? [1]
f. Explain how the lake on the flood plain was formed. [2]
g. Place an X on the diagram to show the location of a tributary valley to the east of the river. [1]
h. State what occurs at point *D* and explain why it occurs. [2]

EARTH SCIENCE

Tuesday, January 18, 1944 — 1.15 to 4.15 p. m., only

Answer all questions in part I, four questions from part II and one question from part III. Answers to the questions in part I should be written on the question paper as directed and handed in with the other answer paper. Answers should be numbered and lettered to correspond with the questions.

Part I

Answer all questions in part I.

Write on the line at the right of *each* statement the *number* preceding the term that best completes the statement. [18]

1. The chief work of an old river is (1) deposition (2) erosion of its bed (3) headward erosion (4) widening of its valley 1____

2. Days and nights are equal in length all over the earth on (1) January 1 (2) March 21 (3) June 21 (4) December 21 2____

3. The monsoon winds that blow over India during the summer come from the (1) northeast (2) northwest (3) southeast (4) southwest 3____

4. Climatic conditions are most uniform in regions that are (1) crossed by mountains (2) distant from the equator (3) located in continental interiors (4) surrounded by water 4____

5. The chemical elements present on the sun's surface can be determined by the use of a (1) radiometer (2) sextant (3) spectroscope (4) telescope 5____

6. A lunar eclipse occurs when the (1) moon casts its shadow on the earth (2) earth casts its shadow on the moon (3) moon's shadow does not reach the earth (4) moon casts its shadow on the sun 6____

7. The chief mineral constituent of sandstone is (1) calcite (2) feldspar (3) mica (4) quartz 7____

8. The amount of (1) carbon dioxide (2) nitrogen (3) water vapor (4) oxygen in the air varies greatly from day to day. 8____

9. Many of the island harbors in the South Pacific are (1) atolls (2) deltas (3) fiords (4) submerged valleys 9____

10. The Hawaiian Islands were formed by (1) flows of lava (2) growth of coral beds (3) submergence of a mountain region (4) sedimentary deposits 10____

11. A small, closed contour line on a map indicates a (1) cliff (2) hilltop (3) steep slope (4) valley 11____

12. Streams are most likely to develop falls and rapids in the stage called (1) early maturity (2) late maturity (3) old age (4) youth 12____

13. Cirrus clouds are (1)thunder clouds (2)high, feathery clouds (3)rain clouds (4)clouds of smoke 13____

14. An increase in the temperature of a volume of air causes (1)a decrease in pressure (2)an increase in pressure (3)an increase in moisture content (4)no change in pressure 14____

15. All the planets of the solar system (1)are the same size (2)have elliptical orbits (3)have satellites (4)revolve about the sun in the same period of time 15____

16. Of the following, the rock that is most easily weathered by freezing and thawing is (1)limestone (2)obsidian (3)quartzite (4)sandstone 16____

17. As the temperature and the dew point of air approach each other, pilots should expect (1)a temperature decrease (2)clear, cool weather (3)fog (4)strong winds and rising temperature 17____

18. The air mass responsible for cold waves that occur in the Midwest is called the (1)continental polar (2)maritime polar (3)maritime tropical (4)superior cold front 18____

Write on the line at the right of *each* statement the term which, when inserted in the blank, will make the statement true. [16]

19. The part of the continent that extends under the ocean is called the ____ 19____

20. Since the earth rotates, winds in the southern hemisphere are deflected to the ____ 20____

21. Wind velocities are measured by an instrument called the ____ 21____

22. In a (an) ____ well, the water rises above the local water table. 22____

23. Winds blow outward from the center of a ____ pressure area. 23____

24. The discoloration and crumbling of rocks is caused by ____ weathering. 24____

25. Anticlines and synclines are characteristic of ____ mountains. 25____

26. Lines on a map that connect places having the same elevation above sea level are called ____ 26____

27. Many bays and inlets along a coast line give evidence of ____ of the coast. 27____

28. Distance north or south of the equator, expressed in degrees, is called ____ 28____

29. Large boulders scattered over a wide area give evidence of erosion caused by ____ 29____

30. The igneous intrusion that forms between sedimentary layers is called a (an) ____ 30____

31. The length of the year is determined by the period of ____ of the earth. 31____

32. Eastern standard time is based on the mean solar time of the meridian that runs through ____ degrees west longitude. 32____

33. In winter, the temperature of ocean areas is ..... than that of land areas in the same latitude. 33.....

34. Clouds are formed when moist air is cooled below the ..... point. 34.....

In *some* of the following statements the term in italics makes the statement incorrect. For each *incorrect* statement write on the line at the right the term that must be substituted for the italicized term to make the statement correct. For each *correct* statement, write the word *true* on the line at the right. [16]

35. *Basalt* is a sedimentary rock that effervesces with acid. 35.....

36. *Comets* are not visible until they have entered the earth's atmosphere. 36.....

37. The *Colorado* plateau is an example of a lava plateau. 37.....

38. At the center of a low pressure area the air *ascends.* 38.....

39. Monadnocks are found in *young* mountain regions. 39.....

40. A wet-bulb thermometer usually indicates a *lower* temperature than that indicated by a dry-bulb thermometer. 40.....

41. A large portion of southern New England is a peneplane formed by *deposition.* 41.....

42. The daily period of insolation at the equator is about *fifteen hours.* 42.....

43. Wind erosion is most active in *arid* regions. 43.....

44. The observed motion of sunspots shows that the sun *revolves.* 44.....

45. Precipitation occurs when saturated air is *cooled.* 45.....

46. The amount of moisture in a unit volume of air is called *relative humidity.* 46.....

47. Most of the large deserts of the earth lie in the *westerly* wind belts. 47.....

48. Limestone always contains the mineral *calcite.* 48.....

49. Soil located on a flood plain is an example of *residual* soil. 49.....

50. The temperature of the air in the troposphere *decreases* with increase in altitude. 50.....

Part II

Answer four questions from part II.

1. It is estimated that rivers carry to the sea more than 12 billion tons of rock material every year.

a. Name *three* ways in which rivers carry this rock load. [3]

b. What causes a river to drop some of the rock material it carries? [2]

c. Name *three* features formed by rivers as the result of deposition. [3]

d. Explain the conditions that cause the formation of *one* of the features named in answer to *c.* [2]

2. *a.* A war correspondent's report from the South Pacific was dated December 15, 1943. It appeared in a New York newspaper on December 14, 1943. Account for this difference in date. [2]
   b. State the relationship that exists between longitude and time. [2]
   c. Describe *one* way by which longitude can be determined on board ship. [2]
   d. The time at Greenwich, 0°, is 12 o'clock noon. What is the time at (1) St. Louis, 90° W., (2) Naples, Italy, 30° E.? [4]

3. *a.* Describe the movement of air within a cyclone (low). [3]
   b. State the approximate rate at which cyclones and anticyclones move across the United States. [2]
   c. Give the general direction of movement of these cyclones and anticyclones. [1]
   d. Predict the weather that may be expected as a well-developed warm front approaches, including state of sky, relative air temperature, wind direction and precipitation. [4]

4. The glacier that covers much of Greenland differs from the glaciers on the slopes of Mt. Ranier, Washington.
   a. Explain the difference in origin between these two types of glaciers. [2]
   b. Compare the type of movement of the Greenland glacier with that of a glacier on Mt. Ranier. [2]
   c. Describe briefly *two* evidences found today that indicate the direction of movement of the ice sheet across New York State. [2]
   d. Account for the formation of two of these features: cirque, crevasse, erratic, hanging valley, outwash plain, terminal moraine. [4]

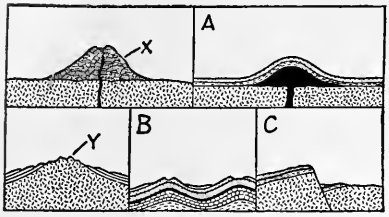
5. Write explanations of *five* of the following: [10]
   a. The same side of the moon is always turned toward the earth.
   b. Rain is a daily occurrence in the doldrum belt.
   c. Wind velocity is less at the surface of the earth than it is 5000 feet above the surface.
   d. The stratosphere is characterized by absence of clouds.
   e. In summer, a breeze usually blows from sea to land during the day.
   f. The position of the star Sirius appears to change during the night.

6. *a.* Explain why caverns are usually found in limestone regions. [2]
   b. Explain how sinkholes are formed. [2]
   c. Sinkholes sometimes fill with water — the sinkhole lakes of northern Florida are examples of this. Describe the condition that produces this result. [2]
   d. State *two* changes that may cause ground water to deposit dissolved mineral matter and name *two* types of deposit so formed. [4]

Part III

Answer one question from part III.

7. The diagrams indicate various ways by which mountains are formed.



a. Name the feature at *x* and explain how it was formed. [2]

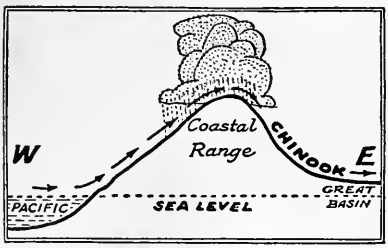
b. What type of mountain is indicated in diagram *A*? Explain how such mountains are formed. [2]

c. Explain what has happened to expose the granite core at *Y*. [2]

d. Name the type of mountain shown in diagram *B* and explain how mountains of this type are formed. [2]

e. What type of mountain is shown in diagram *C*? Explain how such mountains are formed. [2]

8. An air mass starts as a warm moist parcel of air over the Pacific Ocean and moves in over the Coastal Range as indicated by the arrows.

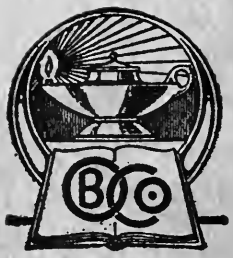


a. (1) Name the type of cloud pictured over the Coastal Range and explain how it forms. [2]

(2) Why should airplane pilots avoid flying through such clouds? [2]

b. Describe *two* changes that occur in the air that descends the eastern slopes and explain why each of the changes occurs. [4]

c. Explain why pilots must allow plenty of altitude when flying to the leeward of mountains. [2]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